

White Paper Report

Report ID: 98498

Application Number: HD5058309

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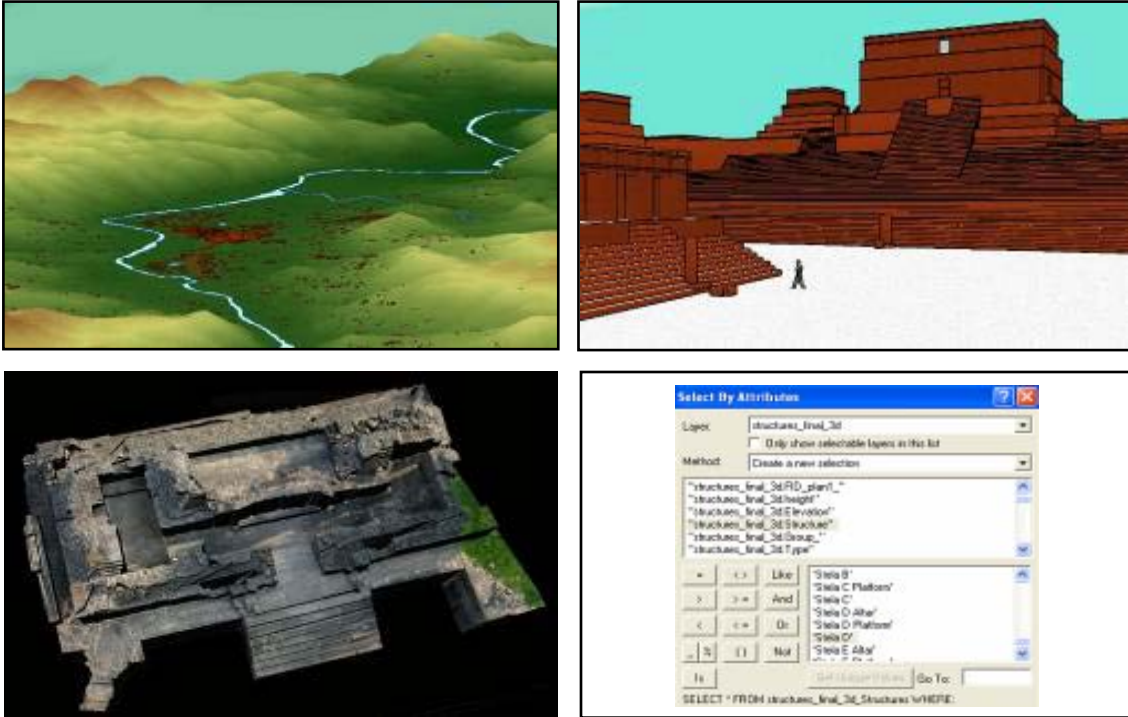
Institution: University of New Mexico

Reporting Period: 4/1/2009-11/30/2009

Report Due: 2/28/2010

Date Submitted: 9/15/2010

FINAL REPORT TO THE NEH
ON THE DIGITAL HUMANITIES START-UP LEVEL I GRANT



Digital Documentation and Reconstruction of an Ancient Maya Temple and
Prototype of Internet GIS Database of Maya Architecture

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Abstract

A NEH Digital Humanities Start-Up Level I Grant in 2009 (\$24,517) supported two international planning workshops to explore the potential of an innovative, international large-scale collaborative project that seeks to reinvent how we integrate 3D objects, virtual reality environments, and GIS maps in a single web environment for use in research and teaching on ancient architecture. The grant period was April 1-November 30, 2009. The two workshops took place in Honduras in April 2009 and Zurich in May 2009 and addressed the challenges and proposed solutions for this project. Specifically, the goal is to develop a new platform for an online, searchable database that brings together GIS maps and highly-accurate 3D models in a VR environment that is linked to GIS database for teaching and research on the spatial, technical, and aesthetic features of ancient architecture for art history, anthropology, and cultural heritage managers. This is important because although computer technologies enable researchers to document ancient architecture in 3D and run multiple reconstructions and analysis, most digital models are not accessible online because the 3D models and scans are too “heavy” to be distributed on open source software.

The case study uses existing digital collections on ancient Maya architecture and a highly-accurate, hybrid 3D model from the UNESCO World Heritage Site of Copan, Honduras that is being developed by the project to develop, test, and demonstrate the platform’s capabilities. Art historians, archaeologists, and museum staff from the University of New Mexico (UNM) and the Honduran Institute of Anthropology and History are working with computer experts from ETH Zurich, FBK Trento (Italy) and the University of California, Merced to design this online tool for research and teaching.

The deliverable for the grant was this white paper, which presents the results of these workshops, and explains the project needs, assessments, research agendas and next steps. As the project results suggest, a small initial investment by NEH has yielded great benefit in the form of project infrastructure, knowledge transfer, and future collaboration. Evidence for this success is evident in that in March 2010 the NEH awarded the project with a Digital Humanities Start-Up Level II grant to build a prototype of the 3D Web GIS database that the project envisions.

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I. The Problem

Modern sensor and computing technologies are changing the practice of art history and archaeology because they offer innovative ways to document, reconstruct, and research the ancient world (e.g. El-Hakim et. al 2008, Gruen 2008, Reindel and Wagner 2009). State-of-the-art imaging technologies allow researchers to document 3D objects to the level of the micron (Acka et. al 2006, Guidi et. al 2009), while VR simulation programs enable reconstructions of ancient buildings and environments (Forte et. al 1997). Virtual landscapes and GIS (Global Information System) maps linked to searchable databases are increasingly able to support interactive analyses of relationships and change over space and time (e.g. Fisher 1993, Llobera 2006). Scholars of ancient architecture can use these new digital tools to bring together buildings, sculpture, and artifacts from locations around the world for comparison and analysis (e.g. Stumpf et al 2003).

The use of 3D technology in art history is an important frontier to explore, because, for example, the pedagogical and research tools art historians and archaeologists have for studying ancient architecture are lagging three decades behind current theoretical approaches to the built environment. While researchers must rely on traditional 2D media of drawings and photographs that limit one's sense of scale and space—recent methods of inquiry include for example, performance studies (e.g. Tate 1992, Ahlfeldt 2004), comparative volumetric studies (e.g. Abrams 1994), phenomenology (e.g. Moore, 1996, Ahlfeldt 2004, Houston 2006)), and access and visibility studies (e.g. Tschan et. al. 2000, Batty and Longley 2003, Richards-Rissetto 2007), all approaches that are engaged with spatial features of architecture. Even for traditional art historical inquiries into dating, style, and socio-political context, the power of a 3D-GIS database for executing and illustrating, for example, a comparative spacio-temporal study of vault heights in eleventh-century German cathedrals—is unparalleled. Remote sensing, photogrammetry, computer-simulated 3D models, and GIS databases, make it possible to perform multi-scalar and multi-perspective experiences and analyses, multiple iterations of hypothetical reconstructions, thereby facilitating researchers and students in interactive virtual explorations and comparative studies(e.g. Hohmann and Kostka 1995).

It is an ongoing problem, however, as to how to publish and store different types of 3D objects, as well as how to mesh them together into a single platform for research and education. How can highly-accurate 3D models of architecture be developed and presented within a VR environment so that they are linked to a searchable 3D GIS database of other digital collections? How do we make such a platform available on open source software—something particularly important in developing countries (home to many important archaeological sites) where internet access is expanding, but access to high-priced software and technical training often is not? In short, how can we design an online, 3D database of ancient architecture with secure levels of access that is useful for scholars, students, and site managers?

II. The Project

What is sorely needed is a central GIS-based, web-interface database (a 3D Web GIS) of ancient architecture that can curate, search, and compare not only digital objects (such as drawings, maps, diagrams, text, photographs, and videos), but also highly accurate 3D scans of sculpture and 3D architectural models in a virtual environment. Within this virtual environment, 2D and 3D objects could be scaled to study relationships between plans, elevations, orientation, materials, artifacts, and inscriptions. Additionally, access and visibility analyses and qualitative studies in lighting and materials could be done. Such a humanities resource would greatly assist scholars to better understand the spatial, technical, and aesthetic features of ancient architecture. It would also help educators to teach these same concepts to their students.

The ultimate goal of this project is to develop a new platform for an online, searchable database that brings together GIS maps and highly-accurate 3D models in a VR environment that is linked to GIS database for teaching and research on the spatial, technical, and aesthetic features of ancient architecture for art history, anthropology, and cultural heritage managers. The case study uses existing digital collections on Maya architecture and a highly-accurate, hybrid 3D model from the UNESCO World Heritage Site of Copan, Honduras that is being developed by the project to develop, test, and demonstrate the platform's capabilities.

Art historians, archaeologists, and museum staff from the University of New Mexico (UNM) and the Honduran Institute of Anthropology and History are working with computer experts from ETH Zurich, F.B. Kessler Foundation, Trento (Italy) and the University of California, Merced to design this online tool for research and teaching. Specifically, this team will reconstruct a particular 8th century temple from the ancient Maya city of Copan, Honduras, and set it within its ancient context. The building, its sculpture, and sections of the ancient city will be recorded with aerial and terrestrial photogrammetry and laser-scanning. The team will use this data to test and develop a 3D digital reconstruction of the temple that will be used for both research and public education. The aerial data will also be added to a GIS database created by this project. This will be donated to the Honduran Institute of Anthropology and History to assist their site managers to monitor the archaeological site and perform conservation and restoration of actual structures where necessary.

To this end, the NEH Start-Up Grant funded two workshops in April and May 2009 to determine the types of data and queries that scholars, educators and perhaps site managers require in a database, and the technologies that exist to create a platform to solve these needs.

The objectives of the workshops were to:

- 1) identify the types of digital collections that exist and determine the high-tech 3D models that are possible to create in a given field (in this case, ancient Maya architecture),
- 2) whether it is possible to offer access to these in a single platform and if so,
- 3) what are the front- and back-end specifications needed to produce such a platform?

The long term goal is to develop a collaborative project that will:

- 1) develop a prototype platform that curates (in a searchable and virtual environment) selected digital collections on ancient Copan, and
- 2) create the most highly-accurate hybrid 3D model of an ancient Maya temple at Copan and its architectural sculpture to date to be tested on the website.
- 3) offer this platform to researchers working at other Maya sites to upload their models and data to engage in comparative analysis of architecture between sites
- 4) create a website tool that serves as a model for 3D digital object management that would have relevance to other fields, humanistic and otherwise. The results may have broad implications for many fields that hope to see these technologies linked together.

III. Comparable Projects

The intellectual inspiration for this project comes from the Perseus Project at Tufts University, which makes literary texts and images relevant for Classics studies available to an international community of scholars and students.¹ Like the Perseus Project, the Chaco Digital Initiative uses a database and visual images to index scanned maps and texts for archaeological sites in Chaco Canyon, New Mexico.² Our goal is to create similar resource for the international community interested in ancient Maya studies, but it will differ from the Perseus project and the Chaco Digital Initiative in that this tool will be able to offer storage and analysis capabilities for 3D data on architecture and associated archaeological data. Of relevance here is Stephen Murray's *Mapping Gothic France* project—a collaborative project linking text, QTVRs, and 2D and 3D images to an interactive map of Gothic cathedrals.³ However, because Murray's project site is not based on 3D Web GIS or VR, its scope differs from that of this Start-Up project. Hypercities, an interactive, hypermedia environment, uses Google Earth as an online platform for collaborative research and education to explore the "layered histories" of cities.⁴ While this project does offer access to 3D SketchUp models, it is not linked to an interactive database or highly accurate 3D models.

As for similar resources that already exist in Maya studies, the only website with a searchable database in Maya archaeology is that of the Foundation for the Advancement of Mesoamerican Studies.⁵ This offers 2D drawings and photographs, and 3D scans of Mesoamerican sculpture. However, these 3D scans are not linked to GIS data, and not available within a VR environment, and are not measurable or comparable in any way. Collaborators from Florida Atlantic University and Longwood University have developed a GIS database of Maya sites, but these are not linked to plans or models of the cities or associated archaeological data.⁶ Meanwhile the number of projects aimed at collecting digital data in the Maya area is increasing. For example, the Caracol, Belize project is using LiDAR to cover 24 sq kilometers to reconstruct the site. Work at Tikal, Guatemala is using laser scanning to reconstruct Pyramid II.⁷ There are ongoing projects to collect digital data, but there is no central place to make them available for research/teaching, or a good platform for people to at least create independent websites to make available these data (even if not in a central database). This is where our project comes in.

Although not in the field of Maya archaeology, there are projects that are developing tools for viewing and analyzing sophisticated 3D architectural models. The two big academic VR environment re-creation labs are the Experimental Technology Center (Diana Favro)⁸ at the University of California, Los Angeles (UCLA) and Bernie Fischer at the Institute for Advanced Technology in the Humanities, University of

¹ <http://www.perseus.tufts.edu/hopper/>

² <http://www.chacoarchive.org/>

³ http://www.learn.columbia.edu/mcah2/html/mcah_news.html

⁴ <http://hypercities.com/>

⁵ www.famsi.org

⁶ <http://mayagis.smv.org>

⁷ http://www.archaeology.org/0905/etc/high_def.html

⁸ etc.ucla.edu

Virginia (UVA), which have collaborated on the Rome Reborn project.⁹ Moreover, Maurizio Forte at UC Merced has led the Virtual Rome project, a VR environment available on OpenSource software. Although the quality of these visualizations is similar to the 3D temple model we plan to develop, our goal is not to create a comprehensive reconstruction of one city but to figure out how to link virtual reconstructions to a GIS database that would allow comparisons and analyses between visualizations of buildings and objects from different cities. To date the most interesting project in this regard is “Fortuna Visiva di Pompei” where reality-based 3D models of buildings and archeological finds are linked to the available superintendence databases for consultation, valorization of the information, and conservation policies planning (Guidi, Remondino et. al 2009, Manferdini, Remondino et. al 2008). While the Pompeii work is a good reference and example, it only includes data only of the Forum of the old roman city and is not linked to a GIS within a VR environment.

An even more innovative part of our project is to figure out how to make VR models and GIS database accessible through a collaborative VR environment, similar to what Maurizio Forte is currently developing at UC Merced and which is intended to be linked to our project here. Finally, David Kohler at UVA has been addressing security and ownership issues in the delivery of 3D cultural heritage objects via the Internet; this is something that will be a concern of our work.

IV. Project Background

The case study for the current project is the UNESCO World Heritage site and ancient Maya city of Copan (Figure 1). Copan—on the southern frontier of the Maya world—is called “the Paris of the Maya world” because of the high-relief stone sculpture found on its temples. Excavations at Copan have been underway since 1885, and archaeologists from the U.S.A, England, Japan, France, and Honduras have shown that the kingdom had a dynasty of sixteen kings that ruled over five centuries (AD 427-820). The four-meter-high portraits of Copan’s thirteenth ruler—King *Waxaklajuun U’baah K’awiil* (reigned AD 695-738) give a sense of this kingdom’s artistic accomplishments. This king commissioned the temple that is the subject of this project. Crowning the acropolis at Copan, it is called “Temple 22” by archaeologists, but it is known as the “Parthenon of the Maya world” because its remarkable sculpture is in museums around the world (Figure 2 and 3). The most famous of these is the Maya Maize God, the “Crown Jewel of Maya Art,” now at the British Museum. Today only the first story remains and it is hard for visitors to imagine the glory of this ancient temple. Fortunately, archaeologists and architectural historians have been working since 1885 to excavate and conserve this temple and determine its original appearance. They are now ready to attempt a reconstruction.

⁹ <http://www.romereborn.virginia.edu/>

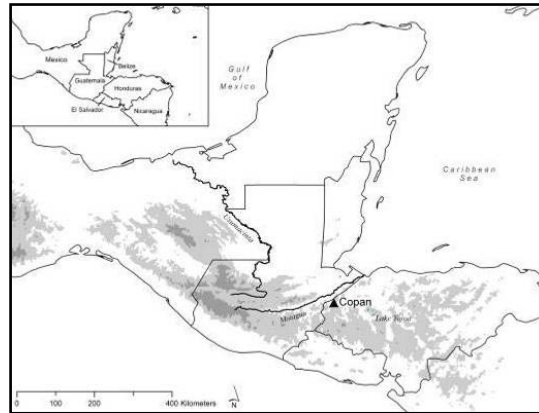


Figure 1. Location of Copan in Mesoamerica.

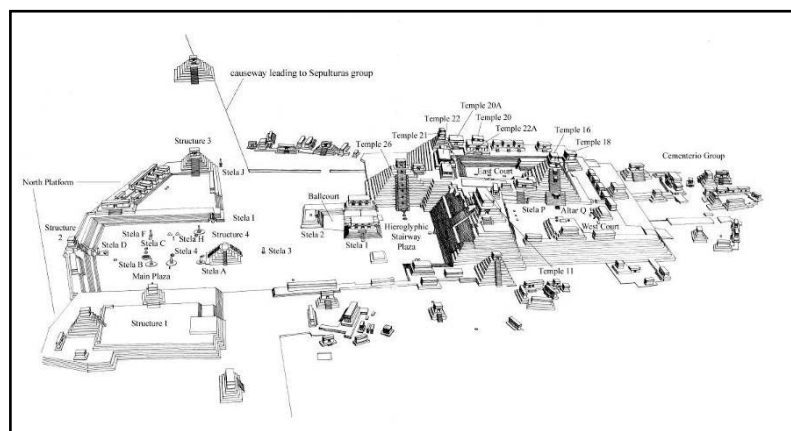
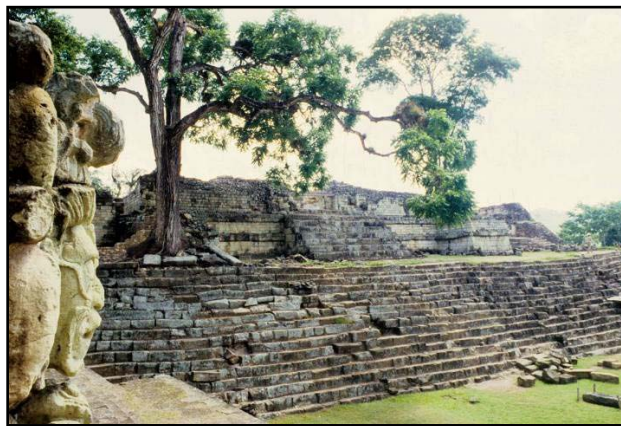


Figure 2. Above: View of remains of Temple 22 in Acropolis (von Schwerin photo). Below: Reconstruction of eighth-century urban center of Copan, Honduras (from Hohmann and Vogrin 1982).



a.



b.



c.

Figure 3. One of eight ruler figures (over 2m high) from the upper façade of Temple 22 (von Schwerin drawing). B and C: Sandbox reconstruction of actual sculpture elements (von Schwerin photos).

Not since the Temple of the Warriors at Chichen Itza, and the House of the Governors at Uxmal were reconstructed in the 1920s and 1930s, has Maya archaeology had such a large sample of preserved sculpture from which to reconstruct a collapsed, highly-complex, temple façade. However, since the 1960s, UNESCO has frowned upon the reconstruction of temples at archaeological sites—promoting “consolidation” instead. While this prevents tourists from being deluded by “imaginary” reconstructions, it presents a dilemma for archaeologists and site managers who want to give the public a sense of the complexity and beauty of ancient Maya architecture. Remote sensing provides a way to offer accurate, scaled models of Maya temples for analysis and viewing.

The international team assembled for this project is highly experienced in computer imaging, containing experts in remote sensing, laser scanning, photogrammetry, 3D modeling, GIS, databases, and Virtual Reality. It also brings together art historians, archaeologists, and site managers who are developing various collections of digital data on Copan, Honduras. The large collaboration ensures international buy-in and sustainability of this project.

While this is a new project, the participants have met before. In 2009 the University of New Mexico and the Alexander von Humboldt Foundation granted Dr. von Schwerin funding to develop this project and to travel to Zurich for initial meetings, training, and planning. Dr. von Schwerin has been interested in creating a searchable database of 3D records of Maya architecture since she began directing the Temple 22 Project in 1998. Temple 22 at Copan has over 3500 pieces of sculpture housed in museum collections

around the world. With funding from Columbia University, the Whiting Foundation, the Metropolitan Museum of Art, UNM, Harvard University, and private foundations, von Schwerin has led fieldwork under the aegis of the Honduran Institute of Anthropology and History (IHAH) to analyze the entire collection of façade sculpture and develop an associated database. To visualize her temple reconstruction, she directed prototype 3D models in 2001 and 2005 (Figure 4).



Figure 4. Exterior and interior views of unfinished 3D reconstruction of Temple 22 from Pilot Study. Created in 3D Studio Max by Laura Ackley. Directed by Jennifer von Schwerin.

These were not completed due to lack of both funding and expertise on how to scan individual sculptures to place onto the 3D model. Meanwhile, Heather Richards-Rissetto constructed a GIS database of Copan's archaeological features and a virtual (SketchUp) model of the ancient city (Figures 5, 6). Other researchers at Copan have related 3D collections that may become available and IHAH has expressed interest in a tool that would allow scaled, secure access to these objects for research and education.

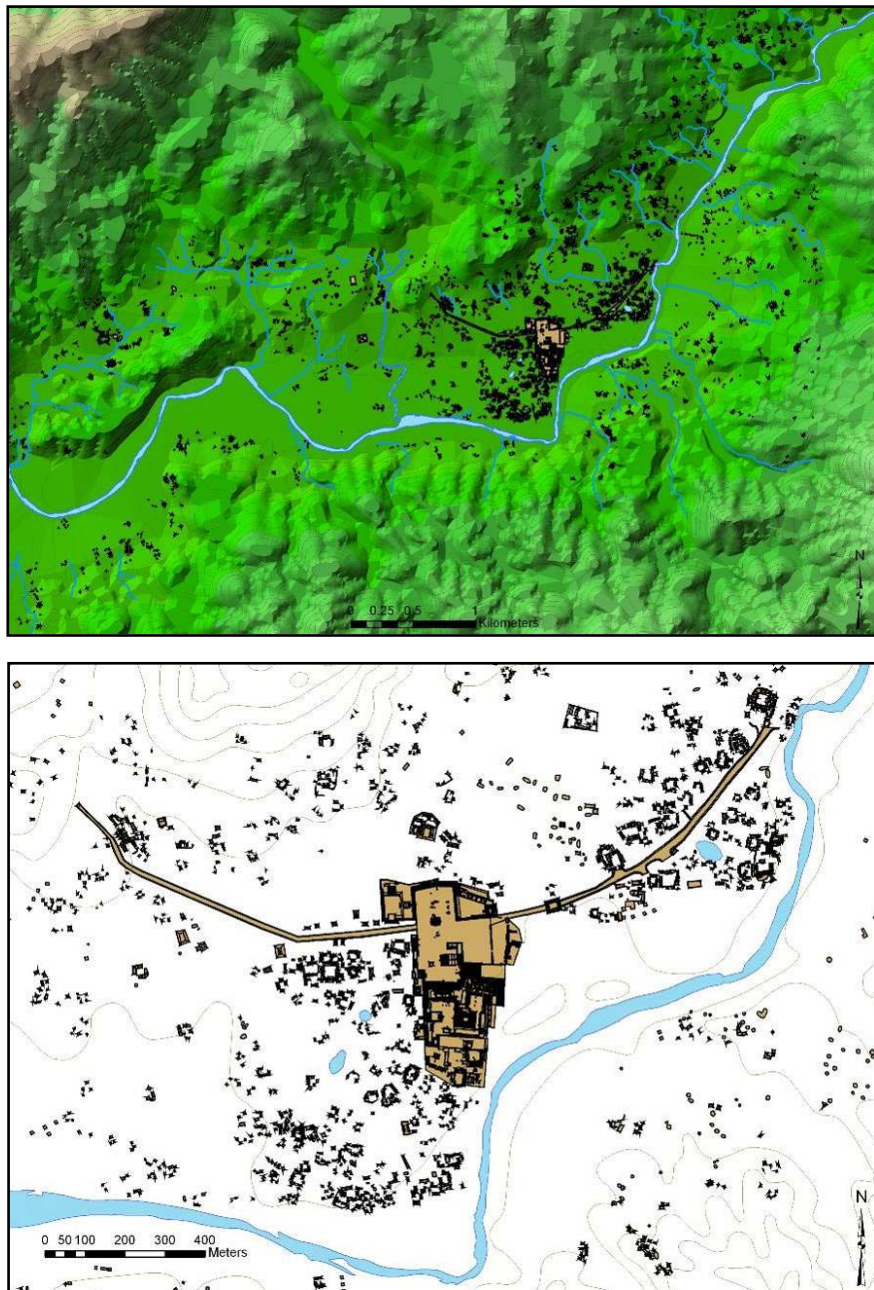


Figure 5. Images of Copan GIS Map designed by Heather Richards-Rissetto (UNM). (Top) Sites in Copan Valley (Bottom) Structures in Urban Core including Main Civic-Ceremonial Complex.

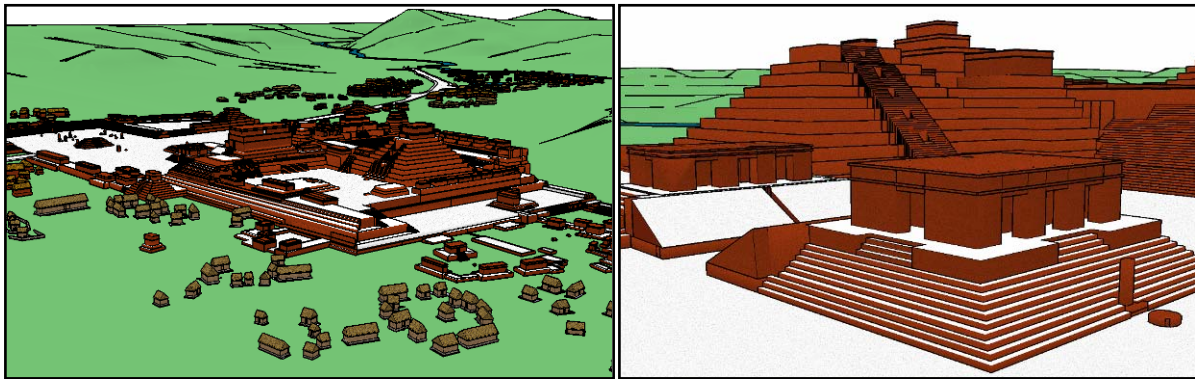


Figure 6. Examples of the 3D SketchUp Model of Copan designed by Heather Richards-Rissetto (UNM). Left: View of ancient city center. Right: View of Ballcourt and Hieroglyphic Stairway at Copan. This model will be made available on the 3D Web GIS.

On the computer technology side, Professor Gruen's team at ETH Zurich and Fabio Remondino's team at FBK, Trento have the ability to generate high-quality 3D models of ancient architecture and to optimize them for a web environment (Figures 7, 8). Between the two groups they use a variety of sensors and methods (laser-scanners, structured light systems, digital cameras, and an Unmanned Aerial Vehicle—i.e. a model helicopter). Von Schwerin, Gruen, and Remondino have begun to create a new model of Temple 22 that will be the most innovative and ambitious attempt to reconstruct a Maya building at this level of complexity. In January 2009, von Schwerin and Richards-Rissetto traveled to ETH for two weeks of training on the modeling and optimization options, and to plan the Copan and Zurich workshops. Meanwhile, Maurizio Forte (University of California, Merced), an expert in open source software for GIS and 3D visualization (Figures 9) has the ability to adapt and modify current platforms (he has used OpenSceneGraph (OSG4WEB) in the past to create a VR environment that might potentially host a GIS database of Maya architecture that can be linked to a VR environment housing the 3D model of Temple 22). Currently Forte is developing a new VR platform—(using Powerwall) to host collaborative, immersive archaeological VR applications. Finally, the ARTS Lab and the Center for High Performance Computing at UNM are focused on research applications of computer technology in the humanities (most recently Maya Skies Project¹⁰) and are interested in collaborating and hosting the database and website.

¹⁰ <http://mayaskies.net>

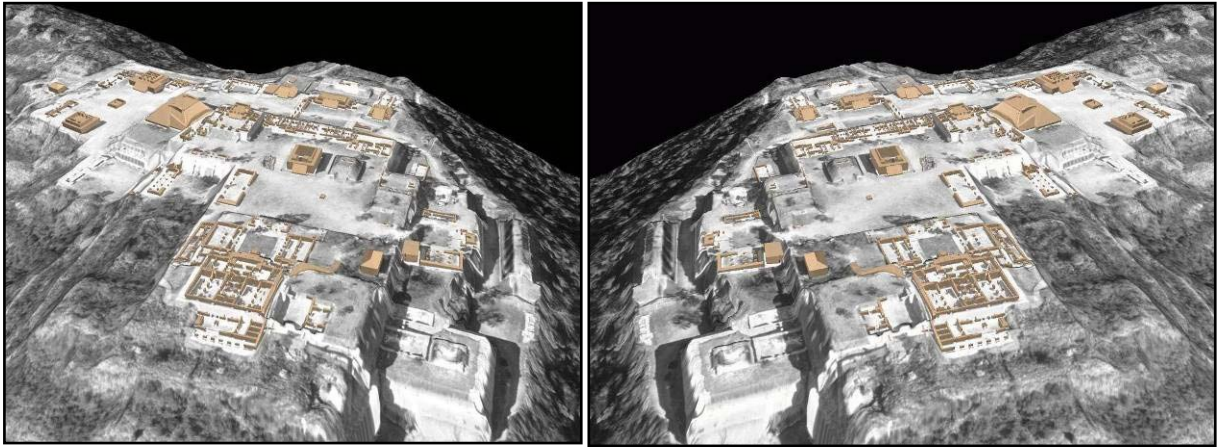


Figure 7. Photogrammetric Model and Reconstruction of Xochicalco, Mexico (Armin Gruen, ETH Zurich).
The same technology eventually will be used to reconstruct Temple 22 at Copan.

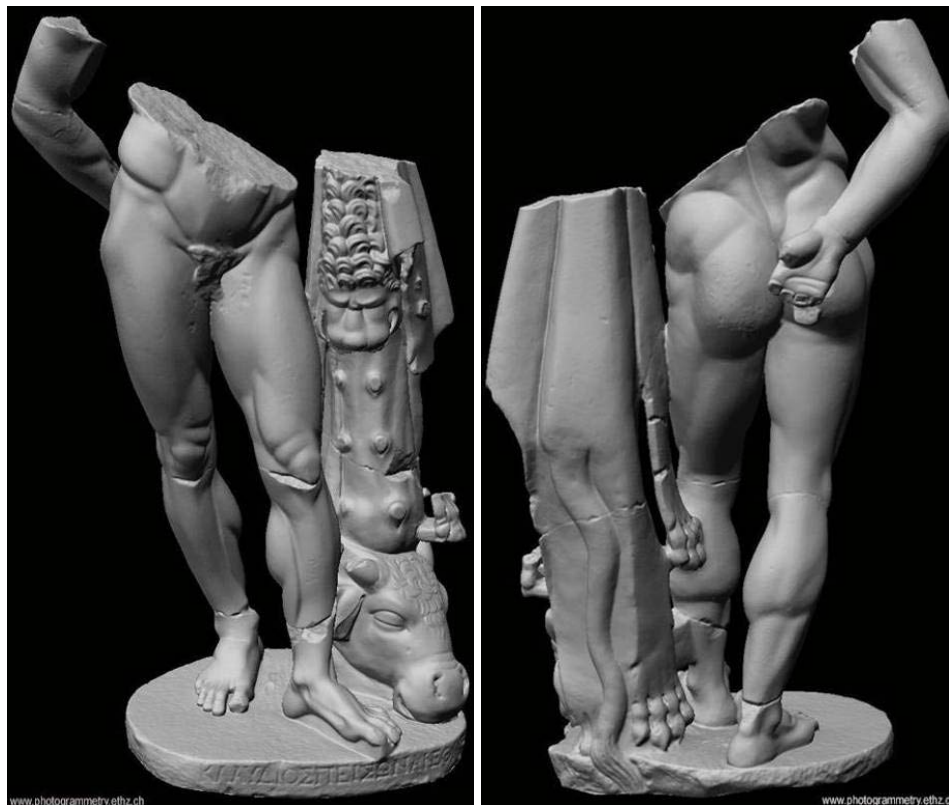


Figure 8. Examples of 3D Structured-Light Scans from Armin Gruen, ETH Zurich. Two views of 3D Scan of Weary Herakles Statue, without texture. Similar technology will be used to generate test scans of sculpture from Temple 22, Copan.

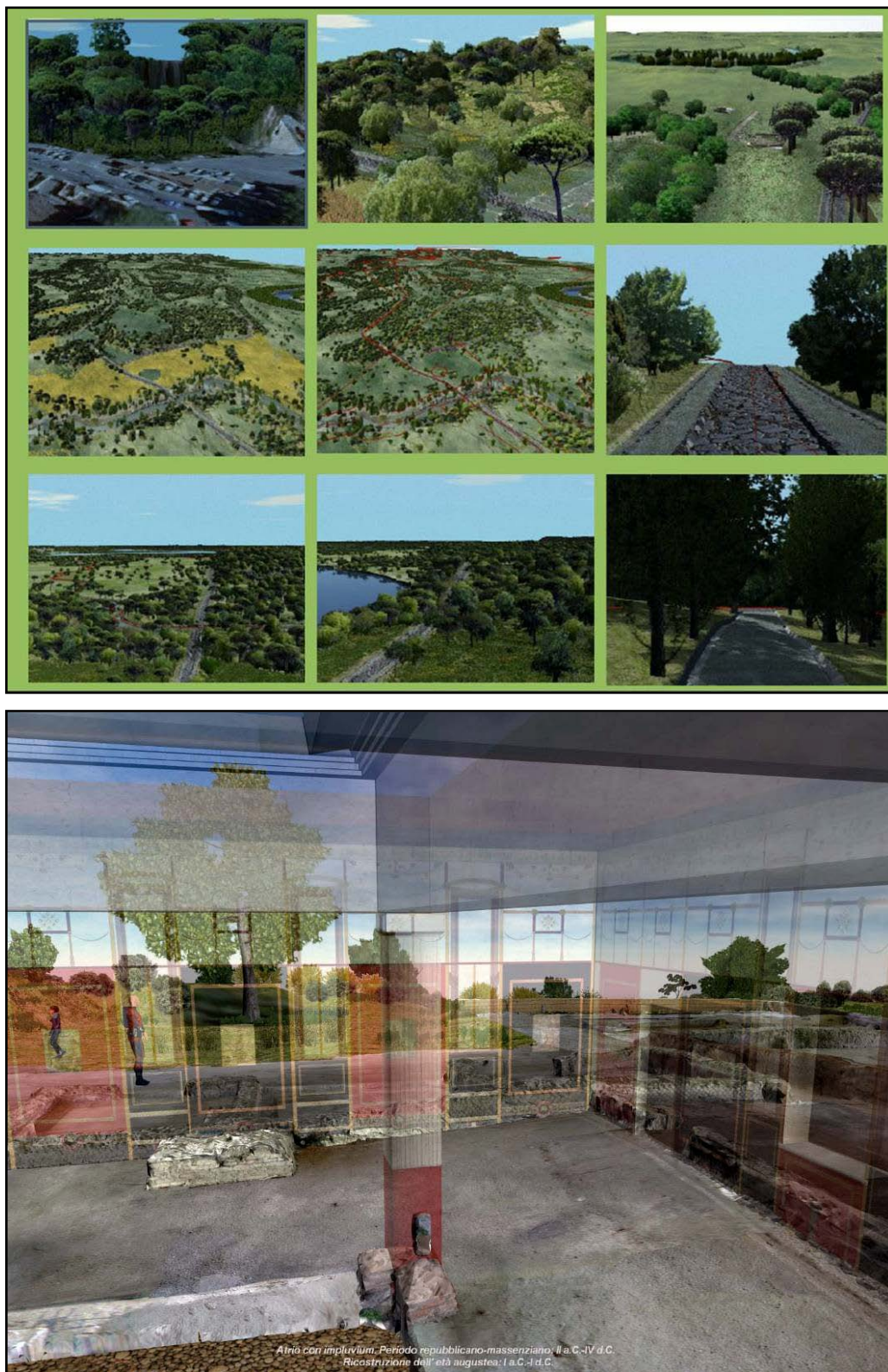


Figure 9. Reconstruction of the Villa of Livia, from the “Virtual Museum of the Ancient Via Flaminia.”
<http://www.vhlab.itabc.cnr.it/flaminia/obiettivi.html> Maurizio Forte.

V. Institutional and Individual Participants, and Advisory Board

The five collaborating institutions and their respective departments are:

- Department of Art History, the Art, Research, Technology and Science Laboratory (ARTS Lab), and the Center for High Performance Computing at the University of New Mexico (UNM), USA
- Honduran Institute of Anthropology and History (IAHA), Honduras
- Institute of Geodesy and Photogrammetry, and the Institute of Historic Building Research and Conservation, Swiss Federal Institute of Technology (ETH Zurich), Switzerland
- 3D Optical Metrology Unit, Bruno Kessler Foundation, Trento, Italy
- The School of Social Sciences, Humanities, & Arts, University of California, Merced, USA



Figure 10. Project Staff Members in Copan, Honduras, April 2009



Figure 11. Jennifer von Schwerin (UNM) is Assistant Research Professor in the Department of Art and Art History at the University of New Mexico and is Principal Investigator of the project. She has worked at Copan for over 10 years and has been funded by the NEH as well as UNM's College of Fine Arts, the Alexander von Humboldt Foundation (Germany), and the German Archaeological Institute to develop this collaborative project. She directs the scope, and content of the project, and organized the Copan and Zurich workshops.



Figure 12. Armin Gruen (ETH) is Professor Emeritus at the Institute of Geodesy and Photogrammetry and at the Institute of Historic Building Research and Conservation, ETH Zurich and Co-Director of the reality-based digital model of Temple 22.



Figure 13. Fabio Remondino (FBK Trento) is scientific researcher at the Centre for Scientific and Technological Research of the B. Kessler Foundation in Trento, Italy, where he leads the 3D Optical Metrology Group. He is Co-Director of the reality-based digital model of Temple 22. He engaged in initial data collection and prepared initial 3D models of various structures and sculptures at Copan and now leads the 3D database development.



Figure 14. Heather Richards-Rissetto (UNM) is Adjunct Professor at UNM and is GIS Coordinator and Database Designer for the project. She designed a GIS for Copan and is responsible for the GIS component of the project.



Figure 15. Martin Sauerbier (ETH) is geomatics engineer at the Institute of Historic Building Research and Conservation at ETH Zurich. He collected data in Copan and identified methods to join the photogrammetrically measured 3D model of Temple 22 with archaeological data using open standards and software.



Figure 16. Henri Eisenbeiss (ETH) is Lecturer and Teaching and Research Assistant at the Institute of Geodesy and Photogrammetry, ETH Zurich. He is specialist in UAV (Unmanned Aerial Vehicle) Photogrammetry and collected aerial and ground-based photogrammetric data at Copan. Since 2008, he is Co-Chair of the International Society for Photogrammetry and Remote Sensing (ISPRS), Working Group (WG) I/V: Unmanned Vehicle Systems for Mapping and Monitoring Applications.



Figure 17. Maurizio Forte (UC Merced) is Professor of World Heritage and is the VR Simulations Director for the project. He has highly visible publications on VR in archaeology and advised this team on how to set this hybrid model within a virtual environment linked to a GIS database and web optimization.

Advisory Board

The Advisory Board assisted with project design, collections access, and advice on future fundraising.

Hohmann, Hasso. Dipl.-Ing. Dr.techn. Univ.-Doz., Professor, School of Architecture, Technical University of Graz.

Martinez, Eva. Sub-Director for Archaeology, Honduran Institute of Anthropology and History, Honduras/

Grube, Nikolai. Professor. Department of Cultural Anthropology of the Ancient Americas, University of Bonn

Hernandez, Mario, Chief of the Remote Sensing Unit, UNESCO

Reindel, Markus, Commission for the Archaeology of Non-European Cultures, German Archaeological Institute, Bonn

VI. Copan Meeting (April 17-18, 2009)

Participants:



Figure 18. Participants of Copan Workshop, April 17-18, 2009, at Visitor's Center, Copan Ruínas, Honduras April 2009

Meeting Summary:

The first workshop was held on Copan April 17-18 with 80 people attending (see Appendix 1 for workshop agenda) (Figure 18). The event brought together cross-disciplinary specialists in art history, archaeology, geomatics, photogrammetry, remote sensing, computer visualization, Geographic Information Systems (GIS), and Cultural Heritage as well as IHAH staff members who are developing or are responsible for various collections of digital data on the archaeology of ancient Honduras. The workshop consisted of a series of discussions, presentations, and software and hardware demonstrations. Participants evaluated current data acquisition techniques, digital collections, state-of-the-art 3D models and discussed how a 3D Web GIS could meet the goals of researchers, educators, and site managers.



Figure 19. The workshop was held in the main hall of the Visitor's Center to the Copan Ruinas Archaeological Park.

The goals of the workshop were to:

- 1) identify the types of digital collections that exist and determine the high-tech 3D models that are possible to create in a given field (in this case, ancient Maya architecture),
- 2) to discuss the potential utility of 3D and GIS technologies for cultural resource management and education in Honduras. Specifically, to discuss the feasibility and potential uses of an online, searchable database that would bring together GIS maps, 3D models, and virtual environments for teaching and research on the archaeological site of Copan and to determine the types of data and queries that scholars, educators, and site managers require in a database.
- 3) gather initial data to begin to create a prototype for the project that tests the feasibility of linking high-quality 3D models in an interactive 3D Web GIS environment.

Friday morning consisted of introductory lectures and then presentations by archaeologists who engage in 3D archaeological work in Honduras, Peru, and Italy. On Friday afternoon talks were given by archaeologists working on 3D archaeology in Honduras. Saturday morning's session consisted of presentations about GIS databases (see Abstracts in Appendix 2).

During coffee breaks and lunches demonstrations were given by UC Merced on using laser scanning to create 3D models of artifacts, by Harvard University on using the Breukmann triangulation scanner to create 3D models of sculpture, and by ETH on using photogrammetry to create 3D models of sculpture and buildings.



Figure 20. Maurizio Forte (UC Merced) demonstrating tabletop laser scanning to create 3D artifacts

Discussion

Saturday afternoon held four round-table discussions, made up of workshop participants who divided themselves into working groups and addressed specific sets of questions and then presented their results back to the main group.



Figure 21. Working Groups and Discussion at Copan Workshop

The working groups addressed the following questions:

Cultural Managers (mainly Honduran Institute of Anthropology staff):

- What digital collections currently exist in Honduras?
- What limitations exist to making this information accessible online?
- To whom should this information be accessible?
- Who are the types of people that consistently need access to this information?
- How could a central database that manages 3D data better assist you in doing your job?

Archaeologists:

- How could a database of 3D data serve your research about the ancient history of Honduras?
- What types of research questions would you want it to help you answer?
- What information would it contain?
- What type of information are you able and willing to contribute?

Technology Experts

- What are the possibilities for constructing a 3D GIS Web database linked via VR? Do other examples of this kind of tool exist in other parts of the world?
- What are the challenges and limitations of such a project?
- What kind of resources are required to accomplish such a project?
- What is the best way to make 3D data accessible for research, management, and general public?

The Public (educators, media representatives, tourism, etc)

- How can we use 3D digital technology to better interest, educate, and stimulate the public about Honduras' ancient history?
- What kind of information do non-experts people want more access to?
- Where should the information be accessible?
- What should the interface look like?

Meals and Networking





Figure 22. Meals provided opportunities to meet other workshop participants and network

The Honduran Institute of Anthropology and History then hosted a lunch and dinner on Friday for all conference participants. The Minister of Culture of Honduras and the Director of IHAH spoke at the evening event. A dinner on Saturday evening for speakers at Don Udo's Restaurant, Copan Ruinas completed the workshop events and provided project members the opportunity to review the events of the workshop and discuss the next steps of the project, helping to prepare for the follow-up workshop in Zurich in May.

Conclusions and Outcomes about User Needs

Participants agreed that a centralized database for 2D and 3D information on Copan archaeology would be extremely helpful and specified a range of needs (see Outcomes section below), but that it is most important for researchers to consider the final outlets and range of future possibilities for their data, before the 3D project has even begun. Workshop participants also agreed that a centralized database can be constructed and used for research and teaching on Honduran Cultural Patrimony, however, those institutions and people that would be involved should first come together to discuss issues such as security and ownership in the delivery of 3D cultural heritage objects via the Internet. It also would be necessary for IHAH to develop an advisory board to address such concerns.

The general consensus was that while a centralized database and platform would serve the needs of cultural resource managers and researchers, the project should offer multiple outputs and/or products. For example, to cope with security issues about access to sensitive data, some parts of the website should be password protected. In addition, animations, interactive walkthroughs, and guided visual tours could provide access to cultural heritage information that is simple and engages the public, especially the youth. Finally, due to the large size of the high-resolution 3D models, it may be best to show optimized models on the website but offer links to download the original highly accurate data.

Based on these discussions, Eva Martinez, Sub-Gerente for Archaeology (IHAH), von Schwerin, and Richards-Rissetto agreed that a pilot project would create a prototype database that would then be presented to an expanded advisory board for evaluation. The goal of the subsequent May meeting in Zurich would then be to determine how to build this prototype according to the needs addressed in the Copan workshop.

VII. Zurich Meeting (May 28, 2009)

Participants attending:

Henri Eisenbeiss, ETH Zurich; Armin Gruen, ETH Zurich; Uta Hassler, ETH Zurich; Mario Hernandez, UNESCO; Hasso Hohmann, TU Graz; Karsten Lambers, University of Konstanz; Markus Reindel, KAAK, German Archaeological Institute; Fabio Remondino, FBK Trento; Martin Sauerbier, ETH Zurich; Jennifer von Schwerin, University of New Mexico



Figure 23. Zurich workshop discussing technical aspects of project

Meeting Summary

The second workshop at ETH Zurich on May 28, 2009 brought together ten individuals (technology experts, architects, art historians, and a representative from UNESCO) to discuss (1) the technologies, funding, front- and back-end specifications needed to produce an online platform that links highly-accurate 3D models to a GIS database in a VR environment, (2) how to design the website and database to meet user needs according to the results of the Copan workshop, and (3) how to optimize the high-tech 3D model of Temple 22 to efficiently display the results in this platform (see Appendix 1 for an agenda of the workshop) (Figure 23).

ETH hosted a lunch and dinner for the participants and offered a demonstration of a helicopter flight to make a photogrammetric survey.



Figure 24. UAV used to acquire aerial photos of Copan (left to right, Richards-Rissetto, von Schwerin, Eisenbeiss and Krättli)

Von Schwerin (UNM) presented the project background and goals and the results of the Copan workshop (Figure 24). Remondino (FBK) and Sauerbier and Eisenbeiss (ETH) presented the results of the data-collection mission in Copan. Hohmann (Graz) presented on previous 3D mapping projects in Copan. Hernandez (UNESCO) presented on a database project planned for the Maya ruins of Calakmul, Mexico and explained the structure of UNESCO and future funding possibilities. Reindel (German Archaeological Institute) was present as an advisory board member. Professor Hohmann agreed to be an additional Advisory Board member and suggested that it would be useful to scan all previous unpublished maps made of Copan that are in storage at IHAH and offer these in the database to researchers. The discussion then centered on proposed solutions for creating a 3D Web GIS Database and Website of Maya Architecture. It was suggested to create a prototype of the tool first, and then issues regarding hosting and assessment, and future funding were discussed, as well as the specific software options and necessary work packages.

Results:

Prototype Development

It was decided the next step is to work out the construction pipeline of the 3D model and WebGIS database. So it was decided that the next phase of the project should involve all collaborating institutions to build a prototype of the database, and build a portion of the 3D model of Temple 22 to test the prototype. The section of the model would just the front façade of the building.

Karsten Lambers suggested that we begin with Conceptual Data Modeling to determine the Vision and Goal of the project –a hard- and software independent model of all entities and their attributes which should be represented in the database. Using this approach, the project is designed as various modules that allow for future expansion of the project with one module serving as the prototype for our project. Options for an open source database were suggested. See Section E of the Outcomes section below.

Hosting and Assessment

ETH Institute of Monument Conservation offered to host the website during development and testing. Since this May meeting, the database design has been contracted to FBK Trento instead as appropriate technical experts are no longer available at ETH. So FBK will be developing the website and will host it during development. UNM will host it for the testing phase.

An assessment plan for the project will include an evaluation workshop once the prototype is completed, and will use von Schwerin and Richards-Rissetto's personal research projects as examples of the utility of the tool.

Future Funding Possibilities and Needs

Ideas for future funding opportunities were discussed. Mario Hernandez said that UNESCO might be able to fund graduate training for Hondurans on the project in Brussels. Armin Gruen pointed out that additional funding is needed to create geometry for the model of Temple 22 and that this is the most expensive part of the project to create digital models as it is the most time consuming.

VIII. Project Outcomes

Overall, the main task of this Start-Up Level I grant was information gathering—specifically, to gain a sense of:

- A. the history of 3D archaeology at Maya cities (using Copan as a case study)
- B. the need for a 3D GIS Database of Maya Architecture (that is, what kind of digital data typically exists for a Maya archaeological site (i.e. Copan) and what are the specific storage, research and accessibility functions that the database should serve)
- C. the most complex kinds of 3D data that currently can be created for such sites that such a database tool would need to manage (i.e. data collecting at Copan with sample 3D technologies)
- D. what solutions can be proposed—that is, how would this database be designed – what are the options we have in terms of components (e.g., GIS database, 3D models, 2D maps, VR) that could be linked or developed?
- E. what kinds of software already exist in the field to create such a tool, and what components of the platform need to be developed ?

A. History of 3D archaeology at Copan, Honduras.

Building on Professor Hasso Hohmann’s presentation on previous mapping projects at Copan at the May workshop in Zurich, von Schwerin and Richards-Rissetto collected additional information to write a history of 3D archaeology at Copan in order to provide background and context for the project, and to understand data availability.

Previous Research Projects

The earliest work that could be called 3D archaeology in Honduras are maps that recorded the three dimensional features of the large civic-ceremonial monuments (Principal Group) at the site of Copan. The first maps were at 1:2500 and were made by Galindo (Graham, 1963) and later, by Stephens and Catherwood in the 1840s (Stephens, 1841). Through time the maps became increasingly more detailed—Gordon (1896) and later Stromsvik (1947) published maps at scales of 1:1500. An unpublished map of Copan’s Principal Group at 1:400 made by Shook is available in the Peabody Museum at Harvard University, while Hohmann and Vogrin’s (1982) map of the Principal Group is at 1:200. In the late 1970s, archaeologists moved their focus beyond the Principal Group to the residential sites of the Copan Valley (Willey et al. 1978; Willey and Leventhal 1979). The Proyecto Arqueológico Copan (PAC I) designed, managed, and carried out the earliest systematic archaeological surveys within the Copan Valley (Baudez et al., 1983). The result was a volume comprised of 24 one-square km maps that contain archaeological sites, contour lines, and hydrology mapped at a scale of 1:2000 (Fash and Long 1983). Following PAC I, Sanders and Webster of Penn State University co-directed Phase II of the Proyecto Arqueológico Copan (PAC II). This phase of the project focused on excavation and large-scale mapping

of elite architectural complexes in Las Sepulturas, a suburb at Copan (Sanders, 1986). Nearly a decade later, Hohmann (1995) created large-scale architectural drawings (many at a scale of 1:100) and 3D reconstructions of many of the excavated buildings from Las Sepulturas, using terrestrial photogrammetry (Hohmann and Kostka, 1995 a,b, Kostka, 1995).

In the late 1990s, Maca (2002) began one of the first GIS maps of the Copan Valley, focusing his efforts on Group 9J-5 and its nearby surroundings in the suburb of Comedero. Richards-Rissetto (2007, 2010) digitized and georeferenced the PAC I maps (covering 24 km²) and integrated them with more recently available large-scale maps to create a GIS for the entire Copan Valley. Currently, the GIS contains (i) vector data of archaeological buildings and monuments, hydrology, and contour lines and (ii) raster data of a Digital Elevation Model (DEM) of the valley (generated from contours ranging from 2-10 meters) and an Urban DEM of the valley's 3000-plus structures (with heights derived from excavations and reconstructions using an applied trigonometric function—see Richards-Rissetto 2007, 2010 for details of methodology).

Since the advent of photogrammetry and remote sensing, surveys of Copan were made at various scales and projects have ranged from LiDAR surveys to structured light scanning of small hieroglyphs. In 2000, the University of Texas at Austin in collaboration with Optech and the US Geological Survey used airborne LIDAR to create a 1m x 1m digital elevation model (DEM) of the Principal Group. 3D models were also made by a Japanese team in collaboration with Cyber University, Japan, and TOPPAN-VR of Toppan Printing Co., Ltd. Japan.¹¹ The structured light scanning 3D projects are led by the Getty Conservation Institute (Gray and Boardman, 2001) and the Peabody Museum of Harvard University to scan the 1900+ hieroglyphs of Copan's Hieroglyphic Stairway with a Breuckmann system. The goal of this latter project is to conserve the stairway and to virtually reconstruct the hieroglyphic blocks in their correct and original order.

Present Research Projects

The workshop held at Copan Ruinas helped to ascertain the scope and scale of present work on 3D archaeology in Honduras (see also Appendix 2 for abstracts of workshop presentations). To summarize, the projects range from remote sensing of objects under the ground via ground penetrating radar (GPR) and electromagnetic resistivity technology to remote sensing of sculpture and architecture to GIS mapping projects, as well as a few educational projects (films by Maca and Nakamura). The workshop proceedings are being published in the journal of the Honduran Institute of Anthropology and History, *Yaxkin*.

¹¹ http://www32.ocn.ne.jp/~maya_copan/

B. Need for a 3D GIS Database of Maya Architecture at Copan

In addition to serving as a conference to determining the current work being done on 3D archaeology in Honduras, the Copan workshop was useful in that the Saturday round-table discussions addressed whether a central 3D database would be useful and what types of information and capabilities (storage, querying, analysis, etc) it should include.

Workshop participants divided into four different groups (cultural managers, archaeologists, educators and media professionals, and technical experts) to discuss their recommendations and concerns regarding such a system.

1. Cultural Managers

The Cultural Managers agreed that a central 3D database would be extremely helpful. They reported that current collections of actual objects managed by IHAH are:

1. The religious art collection and sixteenth century documents in Comayagua
2. Tegucigalpa
 - a. Architecture
 - b. Objects
 1. colonial
 2. pre-hispanic
3. Archaeological sites and Special collections all over the country
4. Copan Archaeological Projects
 - a. Archaeological Project Las Pilas (Florida Copan)
 - b. PICPAC – 1999-2002
 - c. PAPAC 2005-2009
 - d. PROARCO 2003-2009
 - e. PAC I, II, III, - 1977-2009

The group decided a central database to manage these collections and associated data (2D and 3D) would be helpful because it would:

- a. allow immediate access to information
- b allow for the continual update of information
- c. help with keeping inventory
- d. unify formats between currently isolated database
- e. take measures to prevent damage and theft

Limitations that exist to make this information accessible are (1) the lack of computer equipment to host such a system and (2) few people are trained to use computers and the required software. There is also a great deal of restriction on access to information. Cultural managers agreed that people who should

have access to this information are technical staff, researchers, administrators, and authorized students. The people that consistently need this information are researchers and administrators.

2. Archaeologists and Art Historians

The digital data on Copan are held both by the Honduran Institute of Anthropology and History and by the individual institutions of the foreign archaeologists working in Copan. The digital data that IHAH currently manages on Copan include:

1. Library inventory created Harvard
2. Sculpture catalogue created by Harvard in Filemaker Pro format
3. Object collections at IHAH in Copan and Teigucigalpa (Filemaker Pro format)
4. Archaeological sites and maps of Honduras. These are listed in an Excel spreadsheet begun in the 1970s with name, GPS location, and description. The Honduran archaeologists present at the workshop estimated that about 1200 archaeological sites are on this list, while thousands of archaeological sites are known. Of the sites on this list, only 40 percent have an actual file, and a smaller percent of these files include satellite maps or other maps of the site.

IHAH archaeologists were interested to learn what kind of database would be most helpful to manage all of this information, but they expressed concerns about how to manage who should have access to the database. Foreign archaeologists are divided—some would like to see data centralized for research purposes, others are not eager to submit data to central location. In any case, a sample of the types of queries and analytical capabilities that art historians and archaeologists would like include:

1. Comparative volume, material, size, height of vault spring and vault
2. Comparison of sculpture, ceramic, and other artifact data according to building excavated
3. Access to photographs and maps made of the buildings
4. Methods to evaluate access and visibility, and directionality
5. Building plans/elevations, 3D models that can be measured

3. Educators and Media Professionals

This group pointed out that in order to use 3D digital technology to better interest, educate, and stimulate the public about Honduras' ancient history, we must consider the impact of technology on a local level and its communication. This includes producing an integrated message and promoting it through simple and easy access (CD, multimedia, national TV, Virtual Museum over the Internet). It should be free for Hondurans, and organized in a regional way.

The group noted that the participation of national academics in developing this information is small in comparison to foreign institutions. Solutions include Inviting cooperation between IHAH and Honduran universities, and increasing interdisciplinary work.

Such projects should not only be passive involvement, but should also include funds to contribute to the educational infrastructure of Honduras.

The public wants to know about archaeological sites, ancient art, nature, indigenous history, and the economic base of past peoples.

4. Technical Experts

The US and European technical experts did not see in general any limits as to what could be created in terms of a storage and research tool. There was some skepticism, however, with regard to the problem of offering all existing digital data on Copan in a single platform. They pointed out that most 3D model data are too complex to offer completely online, and that then one compromises the visualization when it is offered on the web. There is also the problem of linking VR environments to high-quality 3D models and 3D databases—that is, the problem of real-time access to 3D data. It was suggested to offer some optimized 3D models and then to provide downloadable links to heavier models.

There was a great concern expressed by the technical staff of IHAH, however, with regard to compatability, trained computer staff in Honduras, and system hardware and software requirements. At this point, it was agreed that any database tool that is developed must be temporarily managed and hosted by a foreign institution, with a mirror website at IHAH until such funds are raised to provide human and technical infrastructure to host such a system in Honduras.

C. Pilot project data collection and 3D Model development

Some NEH funding supported the gathering of initial data to be used in the creation and testing of the 3D database. Matching funds and in-kind donations were provided by ETH Zurich, B.F. Kessler, and UNESCO to cover the expenses of the Laser-scanner, remote-controlled helicopter, insurance, labor costs, and some travel expenses .This included:

- 1) sculpture scanning of Temple 22 and its sculpture on East Court
- 2) aerial photogrammetry of Copan for Digital Elevation Model using equipment donated by ETH Zurich
- 3) equipment used
- 4) initial photogrammetric measurements and test-scans on Temple 22 and its sculpture, as well as aerial photogrammetry using a UAV.

Preliminary results of the multi-sensor and multi-resolution 3D Copan project are reported in a paper at CIPA conference in Japan in October 2009 (Remondino et al 2009). The acquired UAV and terrestrial images, together with terrestrial TOF laser scanner data, were processed to derive accurate and detailed 3D models which will be seamlessly combined to produce a multi-resolution digital model of the archaeological area with geometric resolutions varying according to the areas of interest and to fulfill the archaeological needs.

The archaeological area of Copán, partly hidden in the dense tropical vegetation, is constituted by different large courtyards containing buildings, stairways and statues (“stelae”). The pilot project aims are (i) the reality-based 3D modeling of the East Court (ca 35x40m) with its Temple 22 inside the old Acropolis of the site, (ii) the precise 3D modeling of some of the famous Copán’s stelae, (iii) the virtual reconstruction of different structures (mainly pieces of architectural sculpture) located in the local museum and also in foreign museums, together with their re-integration into the reality-based 3D model of the Temple 22. The larger project will face the linking of the digital 3D models with an archaeological database (for data management and access via internet) and the realization of a VR platform for the interactive visualization of the entire modeled archaeological area of Copán. Indeed it is planned to integrate data derived from satellite, aerial images, previous surveys and archaeological missions in order to model the whole larger area of the valley of Copán, which is dotted with Maya and pre-Maya remains.

In this contribution, the first results of the pilot project for the 3D digital documentation of part of the Copán’s site are reported. This field mission was only the first phase of the data acquisition. At this point neither the data acquisition nor the data processing is completed. In the successive sections, we show only a part of the data and the initial processing results.

For the 3D modeling of parts of the archaeological area of Copán, a multi-resolution and multi-sensor approach was adopted mainly for these reasons:

- a) employ the most suited surveying methodology with each artifact contained in the area and derive the most adequate level of information (e.g. conventional photogrammetry for large flat walls, laser scanning for irregular or partially broken structures, photogrammetric dense matching for small detailed decorations, etc.);
- b) introduce a level of redundancy in the acquired data useful (i) to optimize the model accuracy, (ii) identify possible metric errors in the model and (iii) seamlessly merge the boarding areas at different geometric resolution;
- c) fulfill all the measurement and archaeological needs and requirements and achieve a geometric resolution which varies according to the areas of interest and different type of objects.

Sensor and data acquisition

The data (Table 1) consists of UAV and terrestrial images as well as terrestrial TOF laser scanner point clouds. Due to time constraints for the data acquisition only 2.5 days were available for the entire area, including recording work of stelae, corner masks and walls in the local museum. The UAV system is an autonomous model helicopter (Eisenbeiss, 2009; Sauerbier and Eisenbeiss 2010) which mounts a Nikon SRL digital camera with 12 Megapixel, equipped with different objectives. The flying height was

approximately 100 m above ground and the UAV system acquired ca 250 images over the two main courts of the site. Due to the complexity of the site and the archaeological needs, the East-Court and some Stelae were also scanned with a Leica Scanstation2 TOF instrument at various geometric resolutions (Figure 25). In addition terrestrial images were acquired for texture mapping purposes and to model some detailed areas in high geometric resolution and to provide for better edge information in case of smoothing effects of the laser scanner data.

Platform/System	Sensor	Goal	Geometric Resolution
UAV images	Nikon D2X (35 mm and 24 mm lens, 12 Mpixel)	Modeling of the site at medium resolution and texturing from above	1 – 3 cm
Range data	Leica Scanstation 2	Modeling at medium resolution	3 mm – 5 cm
Terrestrial images	Kodak DCS Pro (35 mm and 50 mm lens, 13.5 Mpixel) Nikon D2X (35 mm lens, 12 Mpixel) Sony DCS-T100 (5.8-19 mm zoom lens, 8 Mpixel)	Modeling of small finds and detailed areas at medium/high resolution and terrestrial texturing	1 – 5 mm

Table 1: Multi-sensors and multi-resolution data used for the 3D modeling of some areas of Copán.

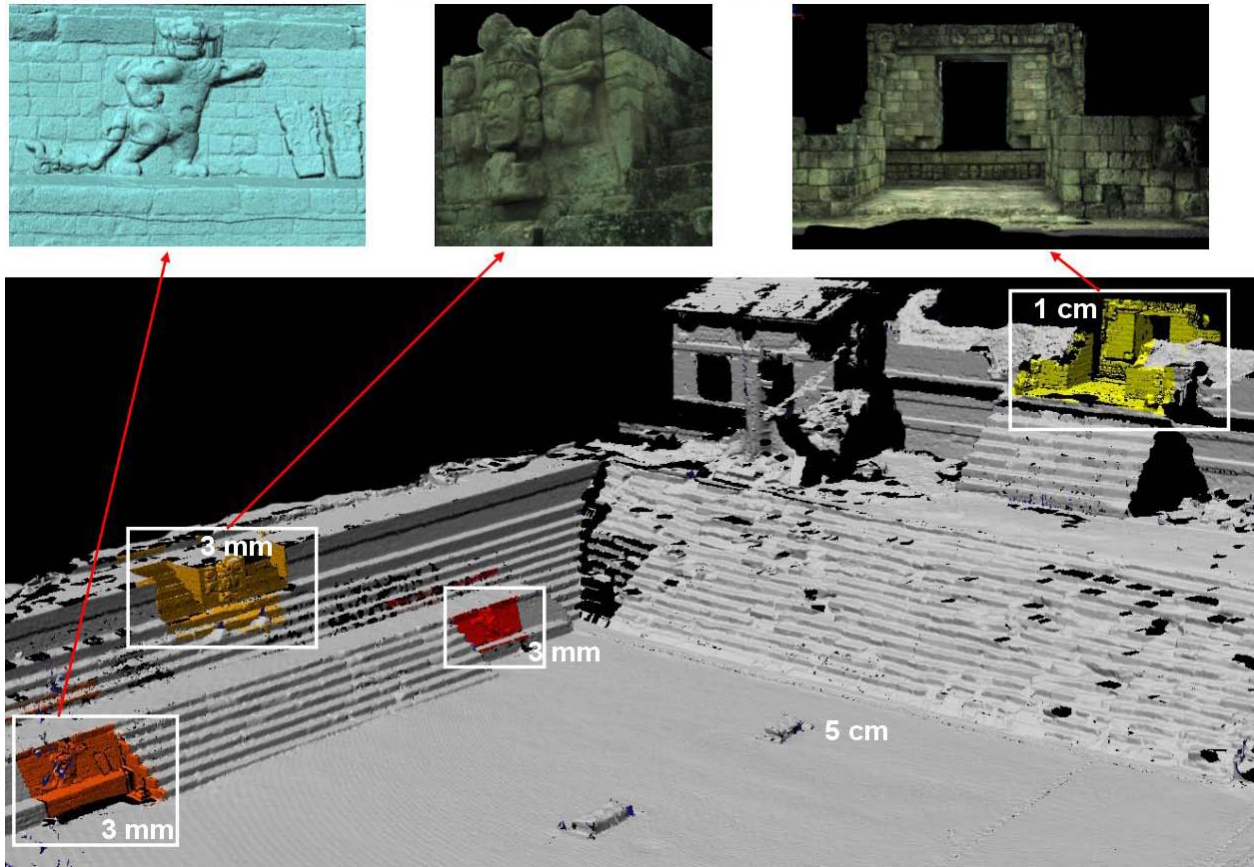


Figure 25. The multi-resolution range data of the East Court area. The geometric resolution spans from the 3 mm of the masks to the 5 cm of the ground and surrounding structures. The holes in the point cloud are mainly due to vegetation and self-occlusions. They will be closed integrating the TOF range data with the point cloud (DTM) derived from the UAV images.



Figure 26. UAV used to collect aerial photos for photogrammetric work at Copan

The UAV was operated using a computer by Henri Eisenbeiss (Figure 26). The backup pilot was Daniel Krättli, a technical assistant and backup-pilot for the model helicopter flight. He works for the private company SwissUAV, which is a manufacturer of Unmanned Aerial Vehicles. Furthermore, he has flight experiences with model helicopters since 25 years.

The model Helicopter Copter 1b was developed by the company Survey-Copter. It is equipped with an on-board navigation system (wePilot 1000) from weControl. The wePilot includes a GPS (Global Positioning System), and an INS (Inertial Navigation System), which allows the mini UAV to perform attitude stabilization, position control and to navigate autonomously. The main specifications of the system are the following:

Mini UAV-system Copter 1b	
Length	2m
Rotor diameter	1.8m
Maximum takeoff	15kg
Payload capacity	5kg
Flight endurance	Max. 45min
Altitude above ground	Max. 200m
Range	2km

The navigation system features the following main characteristics: an altitude stabilization and velocity control, position and RC transmitter sticks interpreted as velocity commands, integrated GPS/INS system, altimeter, magnetometer, payload intensive flight controller, built-in data logger etc. Furthermore, the system consists of a ground control station (a laptop with monitoring software (weGCS), a convertible gimbal for still video cameras like the Nikon D2Xs, communication links, power supply and transport equipment. The ground control station also includes a flight simulator, which allows the simulation of the real flight to be verified.

Before data acquisition using the model helicopter, the accessible data of Copan was evaluated. Furthermore, the existing GIS data set was considered for the flight planning of the system. From prior fieldwork experiences with model helicopters in similar archaeological projects (Pinchango Alto and Sarnen) the attended time for the model helicopter flight, including system checks and flight tests in the field, is 3-5 days, which complies with an actual flight time of 2-3 hours.

The model helicopter flights in Copan were at 50–150m above ground. For the data acquisition of the whole area, we used the higher flying height, while for the detailed scans close-up views resulted in a larger image scale. The whole flight was controlled via operator using the flight control station (Laptop with radio link to the helicopter). During the flight, the operator sent navigation commands to the helicopter to fly to the individual image acquisition points on the predefined flight path. Due to security reasons, the pilot can intervene at any time during the flight. In addition, if the radio link is interrupted during the flight, the model helicopter will fly autonomously to a predefined point (Home point) and an autonomous stabilized landing process will be initiated.

Data processing

The UAV flights were planned to achieve an average footprint of 1 cm over the East Court while for the terrestrial images of the masks the footprint was approximately 1 mm. Some of the image data was

processed with the commercial packages SAT-PP and CLORAMA, developed in the previous years as research works at ETH Zurich (Zhang and Gruen, 2004; Zhang, 2005; Remondino et al., 2008) and now distributed by 4DiXplorer AG (www.4dixplorer.com). The range data (Table 2) were processing with the typical pipeline (Cignoni and Scopigno, 2008) using Innovmetric Polywork. The geometric resolution of the scan data spans from 5 cm of the ground down to 3 mm on the masks and Stelae.

Results

Each single data set was separately processed and then the results will be joined together by means of georeferencing and resampling. The first results from the UAV images are promising (Figure 27), although some manual intervention is still mandatory due to the numerous vegetation occlusions, producing also blunders. The steps and numerous edges of the court will be correctly modeled and this will help to overcome the lack of edges in the TOF range data. Furthermore, the produced 1 cm orthoimage combined with other terrestrial images, will serve to texture the entire East Court 3D model.

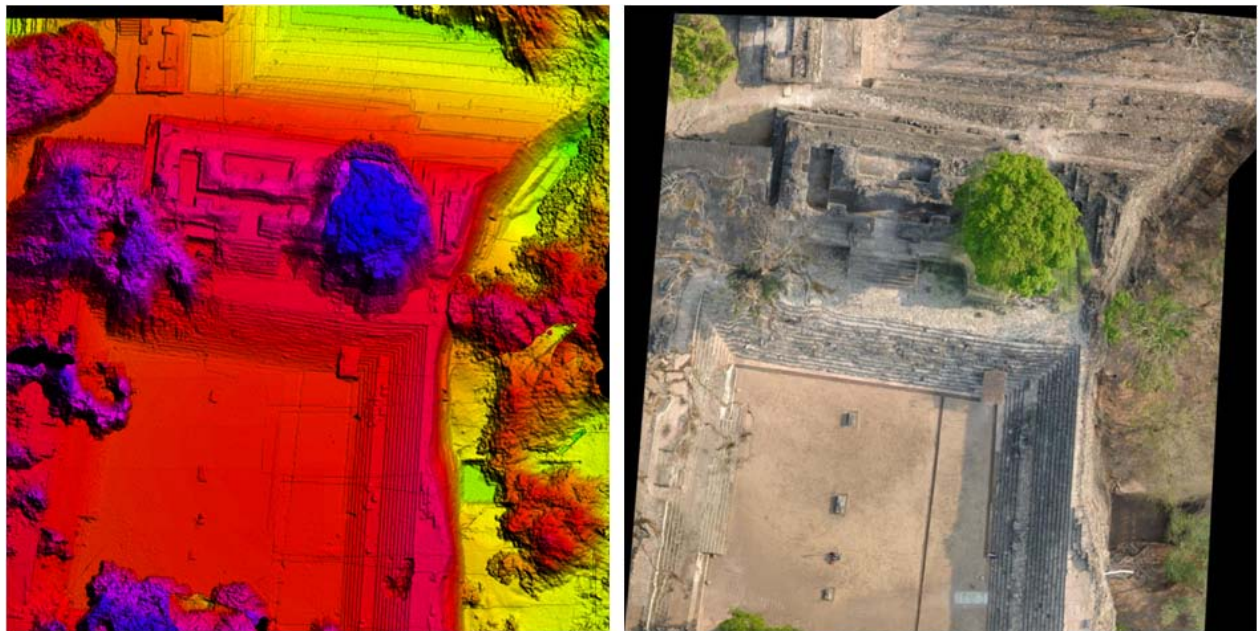


Figure 27: First results from the UAV images over the East court and Temple 22, partly hidden by the vegetation. Left: DSM with 5 cm resolution. Right: Orthoimage with 1 cm resolution.

Stelae A and B, modeled with range data (Table 2) at 3 mm geometric resolution, were then textured with various images to produce photo-realistic 3D models as shown in Figure 28. The time required for the entire modeling was 4 and 5 days respectively.



Figure 28: Range data-based modeling results of the Stelae A (above) and B (below). From left: aligned point clouds, shaded and textured 3D model.

	Sampling step	Stations (points)	Final mesh
East Court	5 cm	5 (15 Mil)	16 Mil
Temple 22	1 cm	2 (2 Mil)	90 K
South Jaguar	3 mm	2 (3.9 Mil)	285 K
JGU Mask	3 mm	3 (4.8 Mil)	290 K
North Jaguar	3 mm	2 (4 Mil)	285 K
Stela A	3 mm	8 (6.6 Mil)	2.7 Mil
Stela B	3 mm	6 (4.9 Mil)	3.9 Mil

Table 2: Range data for the East Court and Stelae, with acquired points, resolution and final polygons.

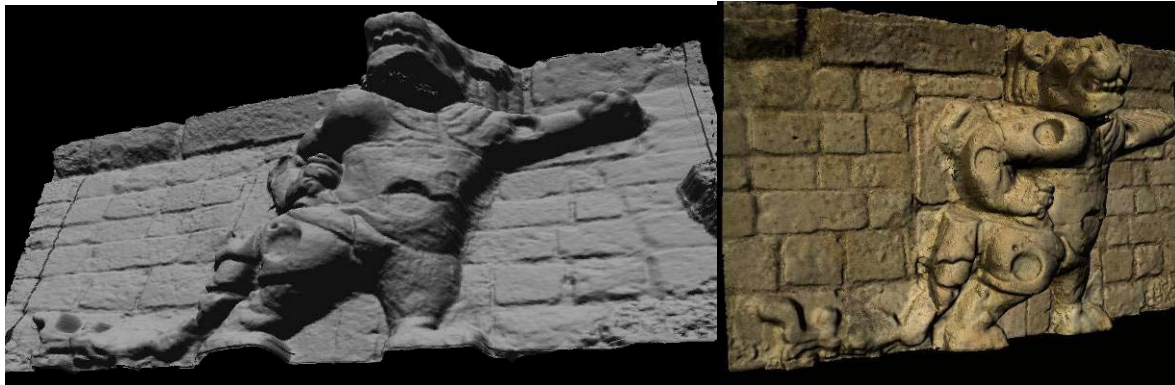


Figure 29: Image-based 3D model of the sculpture shown in Figure 25 derived using 6 images and advanced image matching procedures (software CLORAMA).

From the terrestrial images, a detailed 3D model of a relief sculpture in the East Court was produced as shown in Figure 29. These are the preliminary results of the multi-sensor and multi-resolution 3D Copan project. The acquired UAV and terrestrial images, together with terrestrial TOF laser scanner data, were processed to derive accurate and detailed 3D models which will be seamlessly combined to produce a multi-resolution digital model of the archaeological area with geometric resolutions varying according to the areas of interest and to fulfill the archaeological needs. After the entire modeling phase, the project will face the development of a 3D WEB-GIS and database to store and interactively visualize the data created in the project (as well as coming from other sources) and ultimately be used to assist archaeologists and cultural heritage managers to study and conserve the architecture of the ancient Maya city of Copán.

D. Proposed Solutions for 3D Web GIS Database and Website of Maya Architecture

Our challenge in the Zurich workshop was to determine how to design the platform, website, and database of the 3D WEB GIS database to meet user needs that were identified in the Copan workshop. , That is - how to curate (in a searchable and virtual environment) and interactively visualize selected digital collections on ancient architecture of Copan (and eventually other Maya cities). We began by describing a conceptual design of the envisioned tool.

Conceptual Design

The vision of the project is to develop an interactive website of ancient Maya architecture for research and teaching with a GIS backbone that allows for searches and queries as well as viewing 3D models and environments. This tool would begin with the user accessing a website. Users would see a large map that covers the Maya region and access information via this map. They would then click on the city desired, and then up would come up a more regional map—in this case of the prototype to be built -- the Copan Valley (24 square-kilometers). Using this gateway map, users would then be able to access site maps with the following features: architectural, spatial, technical , and aesthetic. The site maps then serve as gateways to SketchUp and/or VR interfaces. That would be linked to a searchable GIS database with various levels of access depending upon the user. For research, the database link is crucial to allow for the comparison of different site plans, buildings, and objects from different sites. With regard to integrating GIS, 3d models, and VR environments, Maurizio Forte recommends that we will need to separate the 3D database that we are planning for studies of architecture, with what we can do for the 3D GIS/VR landscape. He states that the solution of VR Rome is well tested so there are no problems to use it also for the Copan's GIS.

Actual Data to be included in the Prototype:

For the pilot study, the only Maya city to be included is Copan, and of this, only sections of Copan's architecture—namely—GIS information on the whole city and then more detailed information on the East Court and Temple 22. It decided that we will use the 3D model of Temple 22 at Copan as a prototype of the most complex 3D model available within this prototype website. This model will be a meshing of photogrammetric, structured-light scans, and 3D simulations. Eventually we would like to provide the same data for (1) other buildings at Copan and (2) buildings at other Maya sites.

The data that the project actually has to work with immediately (including both previously existing data and new data from the April 2009 pilot project) include:

1. Georeferenced vector and raster data

These data are from Richards-Rissetto's Copan GIS project and ETH's UAV flight at the April workshop.

- a. **Vector data** - current GIS data covers approx. 24 sq kilometers and includes point, line, and polygon shapefiles of archaeological structures (over 3,000), archaeological sites (n = 594), hydrology, and contour lines. GIS data were digitized from maps that

were mapped at 1:2000 scale (valley) and 1:200 scale (Principal Group). Several attributes (e.g., Group #, Structure #, Height, Elevation) have been coded for these data.

- b. **Raster data**- valley DTM (1m resolution), urban DEM, aerials from UAV flight, viewsheds, and friction surfaces

2. Temple 22 Data

These data are from von Schwerin's Temple 22 Façade Sculpture Analysis and Reconstruction Project (1998-present).

- a. Building plans/elevations - 2D and 3D
- b. 3D models of East Court, Temple, and selected sculptures
- c. 2D photographs, drawings
- d. sculpture database with attributes

3. 3D Data

- a. laser scans of the Temple 22, the East Court, and the Plaza Stelae, the Ballcourt, Structure 4
- b. current reality-based photogrammetric model from ETH/FBK
- c. SketchUp model (model currently exists for Principal Group and two suburbs—Las Sepulturas and El Bosque)
- d. VR model of Temple 22

E. Existing Software Options— Pros and Cons

The challenge here is how to link 3D models to databases and have queries possible in both directions.

OPEN SOURCE database software options:

1. **PostgreSQL with PostGIS (3D).**
 - a. Postgre can handle texture and geometry
 - b. has many users and good support (forums etc.)
 - c. web interface, PHP

The open source database system that best fulfills the project requirements is Postgre SQL in combination with the spatial enhancement PostGIS. Postgre SQL is capable of handling 3D data including texture inside the database, the most important requirement when dealing with large amounts of 3D data and high resolution texture. Furthermore, using PHP as a scripting language the database content can be accessed via websites in read and write mode. While direct access to the tables can be implemented by means of forms embedded into HTML-websites, a suitable interface will have to be developed for graphical access from a 3D viewer. Additionally, PostgreSQL and PostGIS can be used to provide the spatial and attribute data for 2D web-based GIS applications such as UNM Map Server, and the PostGIS spatial data enhancement conforms to the OGC (Open Geospatial Consortium) standards. The PostgreSQL software was successfully

deployed in a project at ETH Zurich for management, editing and storage of 3D models of the petroglyphs of Chichictara, Peru.

2. MySQL (2D)

- a. MySQL develops to commercial software.

3. SQLite

- a. offers spatial data but only 2D not 3D
- b. anyway this is going in commercial direction
- c. too simple for our purpose (no geometry)

4. Oracle

An Oracle database would fulfill all requirements of the project, it can handle spatial as well as semantic data and allows for remote access, e.g. as a data server for WebGIS applications. It has to be noted though that it is a fully commercial and highly complex software that needs significant effort for maintenance, update and in terms of hardware.

5. Collada and KML

COLLADA is a standard for 3D computer graphics based on XML, but clearly oriented to visualization of geometry and with limited capability of semantic data handling. Though it would be possible to enhance COLLADA models by semantic attribute data, this would lead to deviations from the standard and would require development of suitable viewers and query software specifically for the project. Basically the same is valid for KML (Keyhole Markup Language), a 3D format that is known from Google Earth and also based on XML.

6. OSG4Web

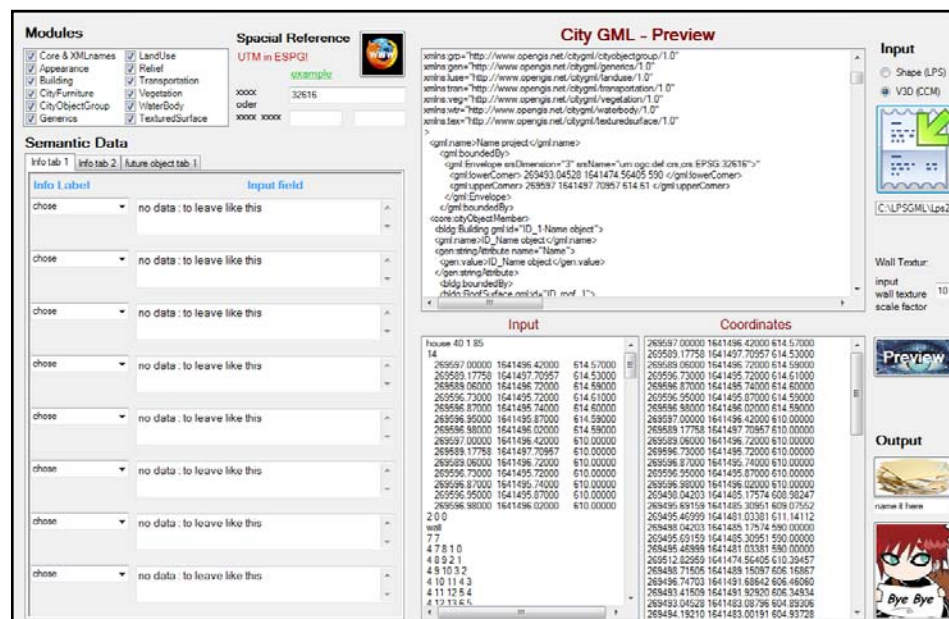
7. CityGML

An alternative option is the XML-based CityGML data structure (see <http://www.citygml.org>), which was developed for management and visualization of 3D city models and was adopted by the OGC as a standard in 2008. CityGML is rather a file structure than a database, nevertheless CityGML data can be stored in some of the above mentioned database management systems (e.g. PostgreSQL and Oracle). CityGML offers the capability to store textured 3D models in a hierarchically structured way. The CityGML structure, compared to other 3D data formats, not only models the geometry of an object but also allows attachment to semantic data to an object's geometry (Figure 30). An object, e.g. Temple 22 in our case, can itself be subdivided into an arbitrary number of tiers representing subparts of the object, like walls, windows, doors, rooms etc. These subparts may inherit attributes valid for the whole object but also have their own individual attributes. A second advantage is that these subparts can be treated as individual objects, which makes them queryable and selectable for analysis functions.

From a geometric point of view, CityGML offers 5 different levels of detail (LoD) which allow to model objects with high complexity (e.g. subsurface objects, furnishing) down to comparably simple objects (e.g. terrain). A wide range of commercial and free or open source software for handling, editing and viewing CityGML data exists¹² and is available for different computer platforms and for visualization via web.

CityGML was investigated and compared to other 3D formats (KML, COLLADA) regarding its applicability in archaeological projects within the frame of a master thesis at ETH Zurich by M. Dreier and a bachelor thesis by L. Steiner supervised by M. Sauerbier and H. Eisenbeiss. The investigation proved that the requirements in terms of semantic data as well as geometric data are fully provided by CityGML, whereas the other two lacked of semantic capability. During the thesis, a 3D model of Temple 22 was measured according to the CyberCity Modeler measurement rules, the measured points then were edited and automatically modeled to roof surfaces and the side walls extruded to the ground. The model is georeferenced in the UTM system Zone 16 North due to the fact that it was derived from the oriented UAV images acquired during the pilot project field work campaign. Two software tools were developed in C# that allow for:

- Transforming CyberCity-Modeler data format V3D to CityGML preserving the topology of the 3D model.
- Adding attribute fields to the CityGML file, and filling these with data.
- A tool for simple attribute query on a CityGML file.



¹² <http://www.citygml.org>

Figure 30. The Graphical User Interface of the software developed for CityGML file generation including attribute definition. The part for semantic data handling is placed on the right side, geometric information is displayed on the right.

The code of both programmes can be made available to project partners for testing and improvement or customization.

Furthermore, CityVU was tested as a first prototype of 3D visualization via web. Though it does not offer capabilities for semantic queries or editing, visualization of the 3D model including an artificial texture that was applied was possible. Nonetheless, for advanced work with the full model CityVU will not suit the requirements formulated above.

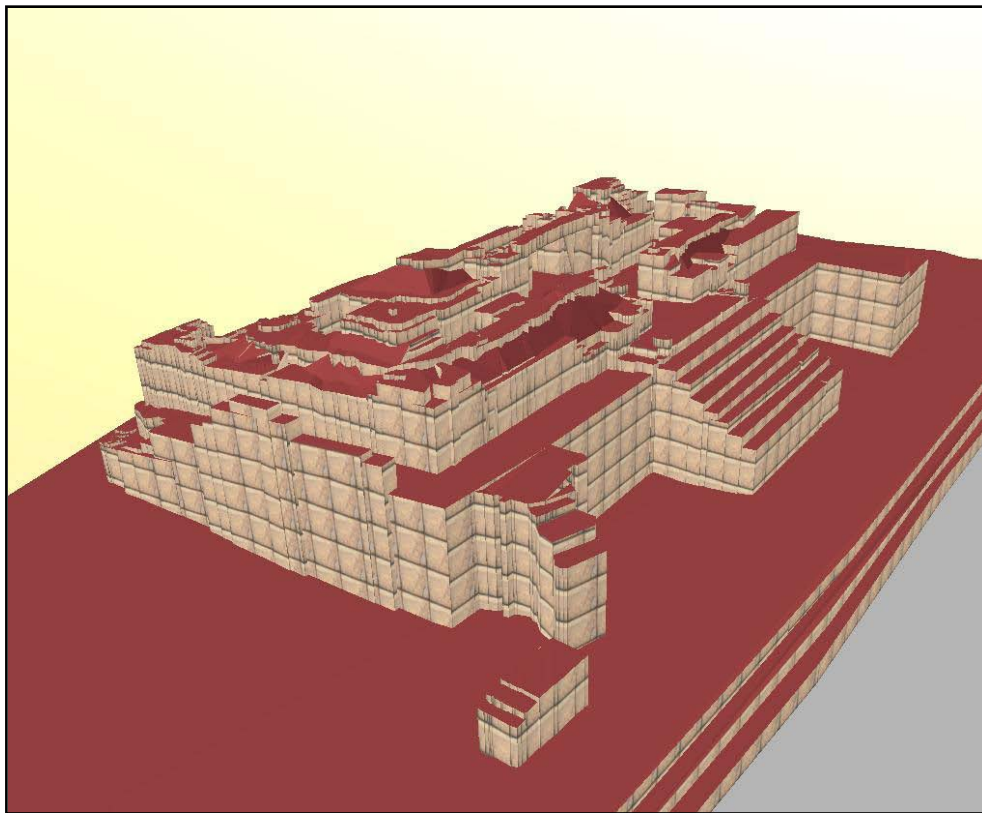


Figure 31. The 3D model of Temple 22 with artificial texture as visualized in Autodesk LandXplorer.

Photorealistic texturing is actually conducted by FBK (F. Remondino), whereas a set of archaeological attributes will be included into the CityGML file of Temple 22 at ETH Zurich (Figure 31).

As CityGML is permanently developed further, it also offers the possibility to integrate archaeological needs into this international standard, e.g. via so-called Application Domain Extensions (ADE), which

already exist for several disciplines and applications (Subsurface applications, Bridge, Building Information Management and others more), but not yet for archaeological requirements.

Suggested viewers for 3D:

- VRML (no interaction, see, turn, small text fields)
- OSG4Web (summarize a comparison to VRMLS)
- CityVU for CityGML
- FABIO's Pompeii program? (MayaSQL - OSG4Web)

Suggested viewers for 2D WebGIS are:

When you know the address of the computer, you can download the GIS data into your own software (and make copies).

- Openlayers
- Mapbender
- Mapserver
- OSG4Web Database (Maurizio)
- normal web GIS software -web feature service and web mapping services. (The ArcGIS education license is expensive - \$ 35,000 and then 1500 per department.)

IX. General Conclusions and Next Steps

The workshops brought together archaeologists, art historians, geographic information technology and computer technology specialists, and VR specialists—all with their own goals and interests and languages (not only disciplinary but also internationally)—and while it was challenging we made real strides in generating conversation between people from these traditionally very different fields. One of the greatest challenges is finding a way to structure the project so that it meets everyone's research needs; however, everyone agreed on the need for archaeological applications of these 3D database technologies. It is clear that the vision we have is possible, but requires expert knowledge for programming, and the problem is large data sets and the computer power to process them.

Overall, we have learned that attempts to develop a platform to link and store 3D data are still in the formative stages—this is still a young field. The current challenges in the field and that the next phase of our project will address are: linking 3D models to searchable databases, and linking VR environments to GIS. For example, at the moment you can query a 3D model only if it has been segmented into different sub-models and each one has been linked to some info available in the database. But this has not yet been demonstrated. To date to our knowledge, no one has built a system in which you can query a database, and call up 3D models to view them in real time.

The project itself is an important step in advancing these technologies for the humanities, as is evidenced by additional funds that have been contributed to the project and its partners since its inception. These include among others a grant from UNESCO for \$20,000 for the project to ETH Zurich to assist with funding for the helicopter flight in Copan, and also a \$70,000 grant to the University of Merced for development of a collaborative VR environment for archaeology, with this Copan project as collaborative case study. Finally, as mentioned in the next section, UNM received a Start-Up Level II grant to develop the next phase of this project.

In March 2010, an NEH Level II grant was granted to UNM to develop a prototype structure of the 3D Web GIS database to demonstrate the workflow and technological pipeline that would be necessary to build the full-fledged tool. The data that will be initially placed in this 3D tool include GIS data for the whole Copan valley, but scanned data only from the East Court and Temple 22 (with associated attribute database). A collaborative VR environment created by UC Merced will also test the model of Temple 22 and reconstruct it as much as possible in the period of the grant. Work will commence June 2010 and we are excited to be able to enter the development stage of the project. Our goal is to have a prototype ready for testing by December 2010.

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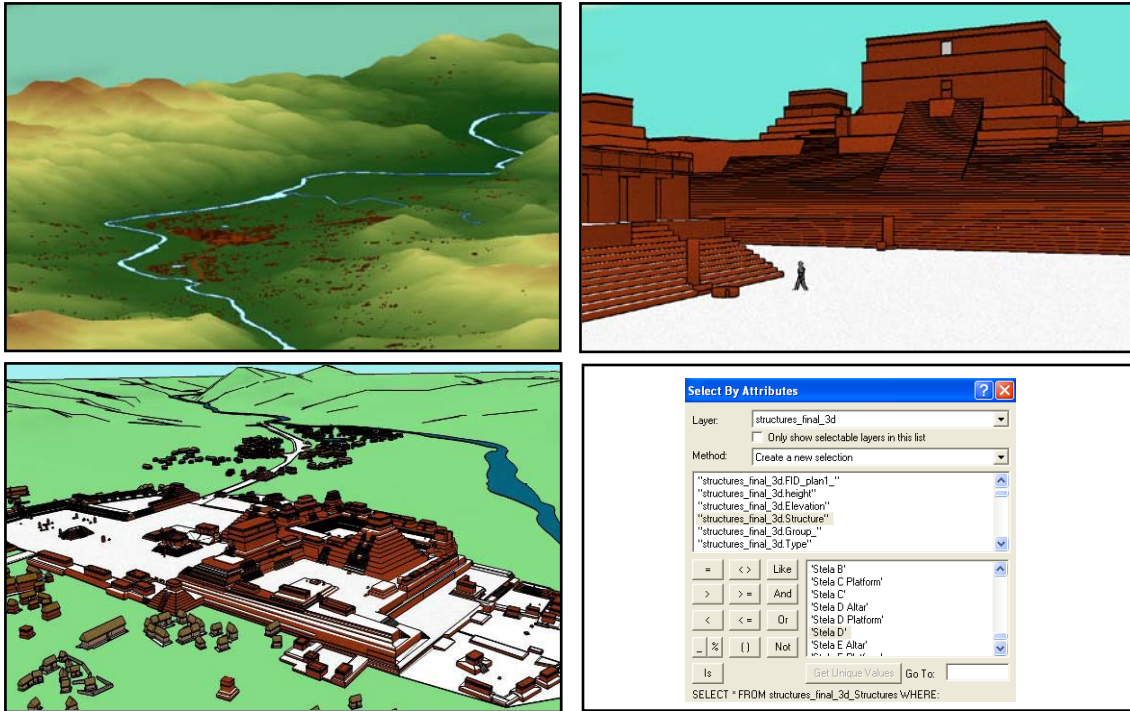
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Images by Heather Richards-Rissetto

International Workshop

3D Archaeology and Cultural Heritage Management in Honduras

<http://www.ihah.hn/taller3d.html>

Friday and Saturday, April 17-18, 2009
Visitor's Center, Copán Archaeological Park, Copán, Honduras

Organizers:

Honduran Institute of Anthropology and History
Tegucigalpa, Honduras

University of New Mexico
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\$15 Honduran Citizens - \$25 Foreigners
Registration deadline: April 10.
To register or for more information see: www.ihah.hn/taller3d.html

Workshop Subject and Goals

Modern sensor and computing technologies are changing the practice of the archaeology of Honduras because they offer innovative ways to document, reconstruct, and research the ancient world. State-of-the-art imaging technologies allow researchers to document 3D objects to the level of the micron, while VR simulation programs enable reconstructions of ancient buildings and environments. At the same time, virtual landscapes and GIS maps linked to searchable databases support interactive analyses. Researchers and cultural heritage managers of ancient Honduras are exploring ways to use these new digital tools for comparison and analysis.

It is an ongoing problem, however, as to how to publish and store different types of 3D objects, as well as how to mesh them together into a single platform for research, education, and management. How can highly-accurate 3D models of ancient objects, architecture or whole settlements be developed and presented so that they are linked to a searchable 3D GIS database of other digital information? How do we make such a platform available on open source software—something particularly important in Honduras where internet access is expanding, but access to high-priced software and technical training is not? What is needed is a central GIS-based, web-interface database (a 3D Web GIS) of ancient Honduras that can curate, search, and compare not only digital objects (such as drawings, maps, diagrams, text, photographs, and videos), but also highly accurate 3D scans of sculpture and 3D architectural models. In short, how can we design an online, 3D database of the archaeology of ancient Honduras with secure levels of access that is useful for scholars, students, and site managers?

This workshop will bring together archaeologists, art historians, remote-sensing and VR specialists, and site managers who are developing various collections of digital data on the ancient history of Honduras. The goals of the workshop are to 1) survey and publish current research and 2) discuss the need for an international, multi-institutional project to develop an online, searchable database that can bring together GIS maps, 2D and 3D data and models, and virtual environments for teaching, research and management of the ancient cultural patrimony of Honduras. Anyone is welcome to attend.

WORKSHOP SPONSORS AND SUPPORTERS



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Bonn, Germany

AGENDA

Friday, April 17

Morning Session: 3D Archaeology and Cultural Heritage -- Global Perspectives

Moderator: Jennifer von Schwerin

- 8:00-8:15 *Welcome and Opening Remarks*
Darío Euraque, Honduran Institute for Anthropology and History (IHAH)
- 8:15-8:30 *New Technologies for Art History and Archaeology: Introduction to the Goals of the Workshop*
Jennifer von Schwerin, University of New Mexico (UNM)
- 8:30-9:00 *UNESCO Initiatives and Projects*
Mario Hernández (UNESCO)
- 9:00-9:30 *Reality-Based 3D Modeling for Cultural Heritage*
Armin Gruen (ETH Zurich)
- 9:30-10:00 COFFEE BREAK*
- 10:00-10:30 *3D Collaborative Environments in Archaeology: Experiencing the Reconstruction of the Past*
Maurizio Forte (UC Merced)
- 10:30-11:00 *Using Unmanned Aerial Vehicles (UAVs) for Archaeological Documentation*
Henri Eisenbeiss (ETH Zurich)
- 11:00-11:30 *Experiences in 3D modeling of sculptures, monuments and sites*
Fabio Remondino (FBK, Trento)
- 11:30-1:00 LUNCH

Afternoon Session: 3D Archaeology in Honduras – Current Research

Moderator: Eva Martinez

- 1:00-1:30 *A Close-up View: Copan Hieroglyphic Stairway Scanning Project*
Alexandre Tokovinine and Barbara Fash (Harvard University)
- 1:30 – 2:00 *3D Geophysical Imaging of Subsurface Geological and Anthropogenic Features at Los Naranjos, Honduras with Ground-penetrating Radar and Magnetic Gradiometry*
Tiffany F. Tchakirides and Larry D. Brown (Cornell University)
- 2:00-2:30 *Teledetección hiperespectral en arqueología. Experiencias y aplicación en yacimientos Centroamericanos*
Juan Gregorio Rejas (Universidad Politécnica de Madrid)
- 2:30-3:00 COFFEE BREAK*
- 3:00-3:30 *A Multi-Resolution, Multi-Source 3D Model and Database of Temple 22*
Jennifer von Schwerin (UNM)
- 3:30-4:00 *Using Valley-Wide GIS for Archaeological Analysis and a Google SketchUp Model of Ancient Copan*
Heather Richards-Rissetto (UNM)
- 4:00-4:30 *Conservation, Science, and Public Education: 3D modeling and Photogrammetry beyond Copan's Principal Group*
Allan Maca (Colgate University) and Clement Valla (Rhode Island School of Design)
- 4:30-4:45 Synopsis and Announcements
- 5:30-6:00 *Demonstration: Triangulation Scanning* (Harvard University)
Location: Copan Sculpture Museum
- 6:30 Wine Reception and presentation of the new Yaxkin
Fuerte Cabañas, Copan Ruinas

Saturday, April 18

Morning Session: GIS Databases for Research and Management: Global Perspectives

Moderator: Jennifer von Schwerin

- 8:00-8:15 *Welcome and Opening Remarks*
Eva Martinez, Sub-Gerente de Patrimonio (IHAH)
- 8:15-8:45 *3D GIS Advanced Databases: An Example from Pompeii*
Fabio Remondino (FBK)
- 8:45-9:15 *GIS Database in Archaeology and Cultural Heritage: Documentation and Archaeological Analysis of the Geoglyphs of Palpa, Peru*
Martin Sauerbier, Markus Reindel and Karsten Lambers (German Archaeological Institute)
- 9:15-9:45 *Virtual Rome Web: an Open Source Project*
Maurizio Forte (UC Merced)
- 9:45-10:15 COFFEE BREAK and Database Demonstrations

Late Morning Session: Reality-Based Remote Sensing Demonstrations

- 10:30- 11:15 Laser scanner - Maurizio Forte (University of California, Merced)
(Location TBA)
- 11:15-12:00 3D Reconstruction with terrestrial photogrammetry - Martin Sauerbier (ETH Zurich, Switzerland)
(Location TBA)
- 12:00-1:00 LUNCH

Afternoon Session: GIS Databases for Research and Management in Honduran Archaeology

Moderators: Eva Martinez and Jennifer von Schwerin

- 1:15-1:30 *Tecnologías Nuevas y la Gestión del Patrimonio Cultural en Honduras*
Eva Martinez, Sub-Gerente de Patrimonio (IHAH)
- 1:30-2:00 *Nuevo Dasfío para el IHAH: Implementación de Nuevas Tecnologías para la Administración del Patrimonio*, Ricardo Rodriguez (IHAH)
- 2:00-3:30 Working Group Discussions /Coffee Service
- TABLE 1: Management
- TABLE 2: Research
- TABLE 3: Technology
- TABLE 4: Education
- 3:30-3:45 Presentation of Results
- 3:45-4:30 Discussion: Integrating Published Material for Research and Cultural Heritage Management
- 4:30 – 5:00 *Closing Remarks and Closing Ceremony*
- Jennifer von Schwerin (UNM)
- Darío Euraque (IHAH)
- Rodolfo Pastor Fasquelle, Minister of Culture, Honduras
- Distribution of Certificates of Participation*

*Posters on view during Coffee Breaks:

Mapa topografico del Grupo Residencial Norte (Grupos 9L-22 y 9L-23) de Copan: Creando un modelo digital de terreno con un modelo volumetrico de las estructuras.

S. Nakamura, F. Castaneda and K. Imaizumi

-Maya archaeology as an application field of Virtual Reality Technology

Toppan Co. Limited. and S. Nakamura

ABSTRACTS AND SHORT BIOGRAPHIES FROM COPAN WORKSHOP PARTICIPANTS

Reality-based modeling for Cultural Heritage

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The latest developments in sensors and data processing technology have strongly influenced many disciplines and have led in many cases to completely novel ways how the respective work is conducted. Archaeology, Cultural Heritage and Virtual Museums are among those fields that have drawn many advantages from this situation. Advanced 3D modeling of landscapes, sites, single architectures, statues, findings and artifacts have given the experts in the field and office new tools into their hands for better analysis and interpretation of processes, developments, and relations.

The automation of image-based and in particular photogrammetric processing has made great progress recently. In addition, Spatial Information Systems provide many functions of interest for data administration and analysis. Finally, visualization and animation software is becoming affordable at better functionality and lower costs.

This presentation, after a brief review of the currently available sensor technology and an introduction into the photogrammetric data acquisition and processing procedures, will show with the help of project examples how this technology works and what kind of products can be generated. We will touch upon the use of satellite, aerial and terrestrial images, but also address laser scanning and structured light systems.

Very often the recording of large sites implies the modeling of objects at very different scales (from large DTMs to small artifacts). This requires the use of different sensors. We will address this issue by presenting results from our Bamiyan, Afghanistan project, where a variety of different images have been used – from satellite images to tourist photographs.

With image-based techniques we can go back in time. We will demonstrate this with our project Tucume, Peru, where old aerial photographs form the basis for information extraction.

Unmanned Aerial Vehicles (UAVs) play an ever increasing role as very flexible platforms for data acquisition in Archaeology and Cultural Heritage. This presentation will give a close insight into this technology, supported by practical examples.

In terrestrial applications we have a large amount of different sensors at our disposal. We show examples from the processing of consumer-type still video images, structured light systems and laser-scanners.

In summary, this presentation will explain the various technologies that are being used in the Temple 22 Digital Reconstruction Project.

Modelación 3D basado en la realidad del Patrimonio Cultural

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Los últimos acontecimientos en los sensores y procesamiento de datos la tecnología han influido fuertemente muchas disciplinas y han dado lugar en muchos casos por completo la forma en que la nueva forma de trabajo respectivos se lleva a cabo. Arqueología, Patrimonio cultural y museos virtuales son algunos de los campos que han llamado muchas ventajas de esta situación. Avanzadas de modelado 3D de los paisajes, lugares, solo las arquitecturas, las estatuas, las conclusiones y los artefactos han dado los expertos en el campo y la oficina de nuevos instrumentos en sus manos para mejorar el análisis y la interpretación de los procesos, la evolución y las relaciones.

La automatización de la imagen y basado en el procesamiento fotogramétrico, en particular, ha hecho grandes progresos recientemente. Además, los Sistemas de Información Espacial de proporcionar una gran variedad de funciones de interés para la administración de datos y análisis. Por último, la visualización y animación de software se está convirtiendo en asequible a una mejor funcionalidad y costes más bajos.

Esta presentación, después de una breve reseña de los que dispone actualmente la tecnología de sensores y una introducción en la fotogramétrico de adquisición de datos y los procedimientos de transformación, se mostrará con la ayuda de ejemplos de proyectos de cómo funciona esta tecnología y qué tipo de productos se pueden generar. Vamos a tocar el tema del uso de satélite, imágenes aéreas y terrestres, sino también la dirección con un haz de luz laser y sistemas de luz estructurada.

Muy a menudo, la grabación de los grandes sitios implica el modelado de objetos en diferentes escalas (de las grandes a los pequeños artefactos DTM). Esto requiere el uso de diferentes sensores. Vamos a abordar esta cuestión mediante la presentación de los resultados de nuestra Bamiyán, Afganistán proyecto, donde una gran variedad de imágenes se han utilizado - a partir de imágenes de satélite de turismo a las fotografías.

Con técnicas basadas en la imagen podemos ir hacia atrás en el tiempo. Vamos a demostrar con nuestro proyecto Túcume, Perú, donde las fotografías aéreas de edad constituyen la base para la extracción de información.

Aviones no tripulados (UAV) desempeñan un papel cada vez mayor de plataformas muy flexibles para la adquisición de datos en Arqueología y Patrimonio Cultural. Esta presentación dará una visión de cerca esta tecnología, con el apoyo de ejemplos prácticos.

En aplicaciones terrestres tenemos una gran cantidad de diferentes sensores a nuestra disposición. Se muestran ejemplos de la transformación de los consumidores de tipo de imágenes fijas de vídeo, sistemas de luz estructurada y escáneres láser.

En resumen, esta presentación se explica las diferentes tecnologías que se utilizan en el Proyecto Copán.

Experiences in 3D modeling of sculptures, monuments and sites

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The generation of reality-based 3D models of objects and sites is nowadays generally performed by means of images or active sensors (like laser scanner or structured light projectors), depending on the surface characteristics, required accuracy, object dimensions and location, project's budget, etc. Active sensors provide directly 3D data and combined with color information, either from the sensor itself or from a digital camera, can capture relatively accurate geometric details. Although still costly, usually bulky, with limited flexibility, not easy to be used everywhere or at every time and affected by surface properties, active sensors have reached a maturity since some years and the range-based modeling pipeline is nowadays quite straightforward although problems generally arise in case of huge data sets. On the other hand, image-based methods require a mathematical formulation (perspective or projective geometry) to transform two-dimensional image measurements into 3D coordinates. Images contain all the useful information to derive geometry and texture for a 3D modeling application. Besides range- and image-data, surveying information and maps can also be combined for correct geo-referencing and scaling. Although many methodologies and sensors are available, nowadays to achieve a good and realistic 3D model containing the required level of detail, the best approach is still the combination of different modeling techniques (and data). In fact, as a single technique is not yet able to give satisfactory results in all situations, concerning high geometric accuracy, portability, automation, photo-realism and low costs as well as flexibility and efficiency, image and range data are generally combined to fully exploit the intrinsic potentialities of each approach. The combination of multiple data sources allow to generate multi-resolution 3D models where each Level of Detail (LOD) is showing only the necessary information while each technique is used where best suited to exploit its intrinsic modeling advantages.



Figure 1: 3D modeling of the Great Buddha of Bamiyan (Afghanistan) and its actual empty niche (A). 3D model of the Pompeii roman forum (B).

The talk will present the actual available reality-based 3D documentation methodologies and the present bottlenecks in the 3D modeling pipeline. Different examples from accomplished projects on large and complex sites as well as statues or architectural monuments will be shown and discussed.

Experiencias en la modelación 3D de esculturas, monumentos y sitios

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La generación de modelos 3D de objetos y sitios a partir de datos reales es hoy generalmente realizada por medio de imágenes o sensores activos (como el escáner láser o proyectores de luz estructurada), en función de las características de la superficie del objeto de la medida, la precisión necesaria, las dimensiones y la ubicación de los objetos, el costo del proyecto, etc. Los sensores activos proporcionan directamente datos en 3D; en combinación con la información del color, por el sensor sí mismo o por una cámara digital, ellos pueden capturar detalles geométricos relativamente precisos. Aunque aún costosos, por lo general voluminosos, con una flexibilidad limitada, no fácil de ser usados en cualquier sitio o tiempo y sensibles a las propiedades de la superficie, los sensores activos han alcanzado una madurez desde hace algunos años; la elaboración de los datos láser para la modelación en 3D es operativa, aunque hay unos problemas en caso de grandes volúmenes de datos. Por otro lado, los métodos de modelación basados sobre imágenes requieren una formulación matemática (geometría perspectiva o proyectiva) para transformar las medidas 2D en las imágenes en coordenadas en 3D. Las imágenes contienen toda la información útil para obtener la geometría y la textura para la modelación en 3D, pero la reconstrucción detallada, precisa y foto-realista sigue siendo una operación difícil, especialmente para sitios grandes y complejos, o si se utilizan imágenes distantes o sin calibración. Además de imágenes y datos laser, información topográfica y mapas pueden ser combinados también para una correcta referenciación geográfica y el cálculo de la escala. Aunque muchas metodologías y sensores están disponibles, hoy el mejor procedimiento para obtener una buena y realista modelación 3D que contiene el nivel necesario de detalle, es la combinación de diferentes datos y técnicas de modelación. De hecho, ya que una sola técnica no es todavía capaz de dar siempre resultados satisfactorios (alta precisión geométrica, portabilidad, automatización, foto-realismo, bajos costos, así como flexibilidad y eficiencia), las imágenes y los datos láser son por lo general combinados para disfrutar a lo mejor las potencialidades intrínsecas de los dos métodos. Esta combinación permite la generación de modelos en 3D con diferente resolución, donde cada nivel de detalle muestra sólo la información necesaria.

El coloquio presentará las metodologías disponibles por la documentación realista en 3D y los problemas presentes en la modelación. Se muestran y discuten diferentes ejemplos de proyectos realizados en sitios grandes y complejos, así como estatuas o monumentos arquitectónicos.

Using Unmanned Aerial Vehicles (UAVs) for archaeological documentation

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In the presentation, the application of an autonomous airborne mobile mapping system for archaeological documentation will be presented. During the last years the author has been involved in several projects related to archaeology using an autonomously flying model helicopter, a so-called mini UAV (Unmanned Aerial Vehicle). Hence, in the presentation the overall motivation of using mini UAVs for Archaeology, the current status of the work with mini UAVs, and recent developments related to archaeological applications will be presented. In the following first the platform and then two specific projects highlighting our improvements for the automation of the photogrammetric workflow using the mini UAV system will be described.

Over the last years, UAVs have become ever more suitable as platforms for data acquisition in photogrammetry. The sensor integration for navigation, orientation and stabilization of the platform now allow for flights without manual control. Furthermore, the recorded data from the flight control system can be used for the automation of data processing. Therefore, the focus at our institute is on automation of the processing of image data acquired from mini UAVs (rotary wing platforms), since these platforms are highly maneuverable. These mini UAVs are mainly used for non-standard photogrammetric applications, but also in standard image acquisition cases where large image scale is required. In addition, the platform can be used when terrestrial image acquisition is not sufficient and oblique aerial images are needed.

Our mini UAV system, developed by weControl, will be described in detail, with a focus on the camera unit of the helicopter, navigation, the flight control system and the flight simulation software.

Documentation of Pinchango Alto (Peru)

The photogrammetric documentation of Pinchango Alto (Late Intermediate Period on the south coast of Peru) was a project conducted in cooperation with the German Archaeological Institute (KAAK, BONN, Germany), the companies weControl, Helicam in Zurich and Riegl Measurement Systems GmbH in Austria. In the talk the preparation of the mini UAV flight, the autonomous flight and image acquisition, the image orientation, DSM and orthophoto generation as well as the comparison of the extracted elevation model with reference data like manual measurements, and a DSM produced out of terrestrial laser scanning will be presented.

The application of the UAV, allowed the Late Intermediate Period site of Pinchango Alto to be documented in high resolution and with high accuracy in basically one day of fieldwork. The mini UAV system used at Pinchango Alto permitted a 3D model to be produced according to the specific requirements of archaeological analysis. This model of Pinchango Alto is a good starting point for architectural, structural, and functional study of a typical large Late Intermediate Period site in the region of Palpa and Nasca.



Figure 1: Pinchango Alto.

3D Model of castle Landenberg

Here we describe the workflow of 3D modelling and photorealistic texture mapping based on close range imagery acquired with our mini UAV and in terrestrial mode. For generation of a highly accurate 3D model, a combined photogrammetric processing of these images was required. The conducted workflow consists of the following steps: project planning, flight planning, terrestrial and aerial image acquisition, camera calibration, control point measurement using GNSS (Global Navigation Satellite System), measurement of control and tie points in the images using the photogrammetric close range processing software Photomodeler 6, modelling and texturing of the object and visualization of the finalized model. Finally we achieved an excellent high resolution textured 3D-Model of the castle Landenberg with combining terrestrial- and UAV Photogrammetry.



Figure 2: Textured 3D model of Castle Landenberg.

Finally, based on our recent achievements, the benefits of using autonomous mini UAVs as platforms for archeological documentation will be discussed.

Using Unmanned Aerial Vehicles (UAVs) for archaeological documentation

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3D Collaborative Environments in Archaeology: experiencing the reconstruction of the past

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The key idea is to approach the use of virtual reality collaborative environments from a different perspective and using on line platforms. Although currently we can count many applications of 3D virtual reconstructions in archaeology and in computer graphics, there are no meaningful example of 3D scientific collaborative environments for virtual reconstructions and simulation's goals. This gap is mainly due to the emphasis on the communication aspect and the final reconstruction, while little attention is given to the validation and transparency of the reconstruction process. One of the critical point in the reconstruction is in the capacity to show the relations (spatial-temporal, semantic, symbolic and interpretative) between the final result (the "model") and the interpretation process (the "input"). The virtual reconstruction is basically a simulation process and it needs a cooperative work and a discussion in all the stages of research: to show a spectacular model just visualizing the final result has no impact in the interpretation process. In this case the scientific community has just to accept or reject the final interpretation without the ability to discuss it in any term. Therefore the reliability of the reconstruction is evaluated mainly "by the authorship" of distinguished scholars and not by a deep and transparent analysis of the research path.

In our projects we changed this traditional approach by providing a collaborative simulation platform where multiple users can interact in the 3D space sharing the content and the 3D graphic libraries in the same cyber space. This approach is quite revolutionary in virtual archaeology since it moves the scientific work of validation-interpretation to the stage of a simulation interactive process or, better, to a cyber-archaeological process. Libraries, models, textures and objects float in the cyberspace in a potential stage of simulation, open to the capacities of experts and end-users to finalize them in a continuous interaction between interpretation and communication. This simulation gives the research project a holistic vision, a 3D open recontextualization of objects, sites and landscapes from micro to macro scale.

This kind of research gave us the opportunity to integrate different technologies in one stage and in different archaeological fieldwork: remote sensing, digital photogrammetry, 3D long range and close range laser scanning, GIS, photomodelling and computer vision. This integration has produced a significant quantity of 3D data, then modeled and optimized for a 3D interaction in the cyber space. In this paper different archaeological case studies will be presented.

3D Collaborative Environments in Archaeology: experiencing the reconstruction of the past

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A close-up view: Copan Hieroglyphic Stairway scanning project

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Since 1998, the Honduran government and the Peabody Museum of Archaeology and Ethnology have collaborated on researching various methodologies for replication and preservation of Copan's sculpture, particularly the Hieroglyphic Stairway. This presentation centers on the background and some preliminary results of the 3D scanning project now underway by the CMHI at Copan, Honduras. We will discuss the rationale for recording Maya hieroglyphic inscriptions like the Copan Hieroglyphic Stairway in high resolution using Breuckmann smartScan 3D or similar digitization systems, focusing on standard research and preservation requirements. A step-by-step account of the scanning process will be presented. We will conclude by highlighting the challenges with storing, updating, and publishing 3D data.



Figure 1: The Copan Hieroglyphic Stairway

Una vista detallada: El proyecto del escaneo de la Escalinata Jeroglífica de Copan

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Los investigadores de la civilización Maya que hace tiempo floreció en las tierras bajas de México, Guatemala, Belize y Honduras han siempre estado en una carrera contra el tiempo para investigar y conservar el inestimable patrimonio cultural de los Mayas. El Museo de Peabody de la Arqueología y Etnología y particularmente el Corpus de las Inscripciones Jeroglíficas Mayas han sido entre las instituciones que por más que 100 años han dirido estos esfuerzos.

Los métodos tradicionales de la documentación de la escultura Maya como la fotografía y los dibujos no alcanzan a registrar todos sus detalles de todos los ángulos posibles de vista con varias condiciones de iluminación. Durante muchos años, la única solución del problema era hacer los moldes de las esculturas o de las fachadas de los edificios. Pero la producción de un molde puede dañar al original. Además, el almacenamiento y la conservación de los moldes pueden ser muy costosos. Por lo tanto, desde hace 15 años, el Corpus ha explorado las oportunidades ofrecidas por la tecnología de la documentación digital en tres dimensiones. Haber probado varios sistemas de digitalización, el Corpus eligió al “smartSCAN 3D” producido por la empresa alemana Breuckmann porque este equipo correspondía bien a nuestras expectativas con respecto al precio, eficiencia, y la variedad de las aplicaciones potenciales del sistema.

Desde Agosto de 2008, el Corpus junto con el Instituto Hondureño de Antropología e Historia (IHAI) ha usado smartSCAN 3D para documentar la famosa escalinata jeroglífica de Copan en Honduras. Este proyecto continúa en el presente y ha producido, en adición a los datos preciosos, una experiencia importante de la aplicación de este equipo para la documentación de los monumentos Mayas.

smartSCAN y los sistemas similares producidos por Breuckmann usan la luz estructurada y la fotogrametría para construir los modelos 3-D de la superficie del objeto en alta resolución. La información acerca la textura (color) de la superficie también es registrada. Varias combinaciones de lentes permiten registrar la superficie con diferentes “campos de vista” y resoluciones. No es necesario de introducir algunas marcas exteriores para alinear los escaneos individuales.

Las decisiones iniciales y ciertas fases del proceso del escaneo merecen una discusión particular que será ilustrada por algunos proyectos finalizados de varias partes de la escalinata jeroglífica. Buena planificación y el entendimiento de los objetivos del escaneo (conservación, investigación, presentación, reconstrucción) son esenciales para tener éxito en la documentación de los monumentos usando smartSCAN y otro equipo similar.

3D Geophysical imaging of subsurface geological and anthropogenic features at Los Naranjos, Honduras with ground-penetrating radar and magnetic gradiometry

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Three-dimensional ground-penetrating radar (GPR) data and magnetic gradiometry data were acquired at the archaeological site of Los Naranjos, Honduras during the summers of 2003 and 2007. Los Naranjos, located on the northwestern shore of Lake Yojoa, is one of the earliest village sites in Mesoamerica, with continuous occupation dating from the Early Formative to the Terminal Classic Periods (ca. 1100 B.C. – A.D. 1200). The goals of these geophysical studies were to augment the limited archaeological excavations of the joint Cornell University – University of California, Berkeley field program by providing a detailed three-dimensional image of the subsurface within the Principal Group, where some of the largest earthen platform mounds were constructed early in the history of the site. These results help define how Formative Period communities developed in relation to large earthen platform mound constructions.

GPR proved especially effective at delineating Quaternary stratigraphy and identifying localized buried features. Depth of penetration was variable, poor (0.5 m) in places but generally excellent (5 m). Onlap of strata, unconformities, and faults provide important clues regarding the geological history of the site. Numerous diffraction hyperbolae and amplitude anomalies suggest potential archaeological features buried throughout the site. Correlation between magnetic anomalies and GPR-imaged features implies a range of lithologies and artifact compositions. The GPR results have been useful at distinguishing natural from anthropogenic features at the surface and are consistent with clay cores to the large earthen platform mounds. Although GPR surveys at other sites in Honduras have had limited success, the Los Naranjos results show considerable potential for this technology in defining geological setting and mapping buried anthropogenic structures.

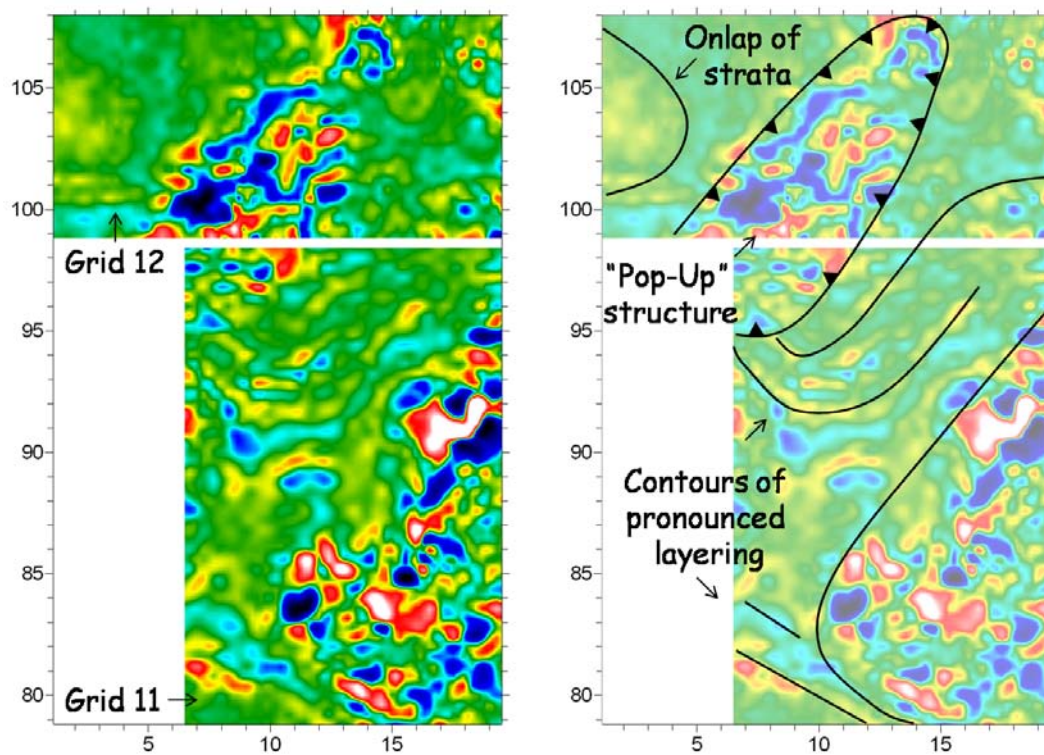


Figure 3: Plan view image of GPR data collected within Grids 11 and 12. Depth range is 1.125 m to 1.25 m.

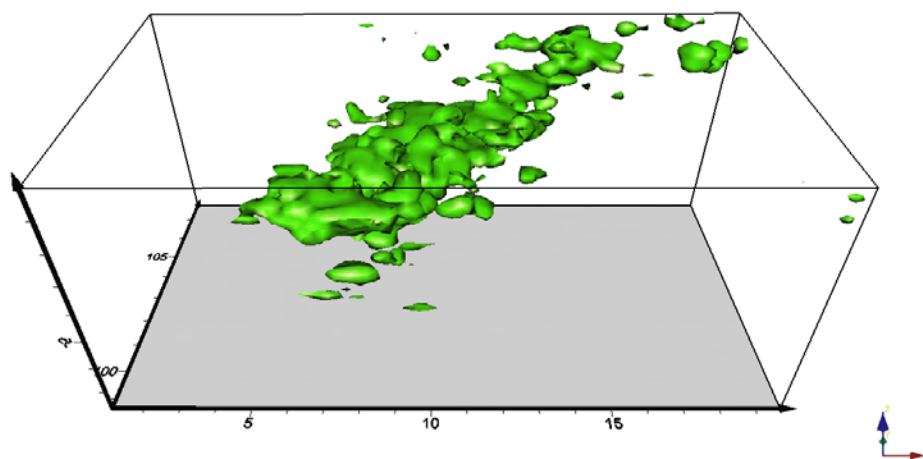


Figure 4: Oblique view of an isosurface rendering of Grid 12 GPR data, showing the “pop-up” structure imaged in Figure 1.

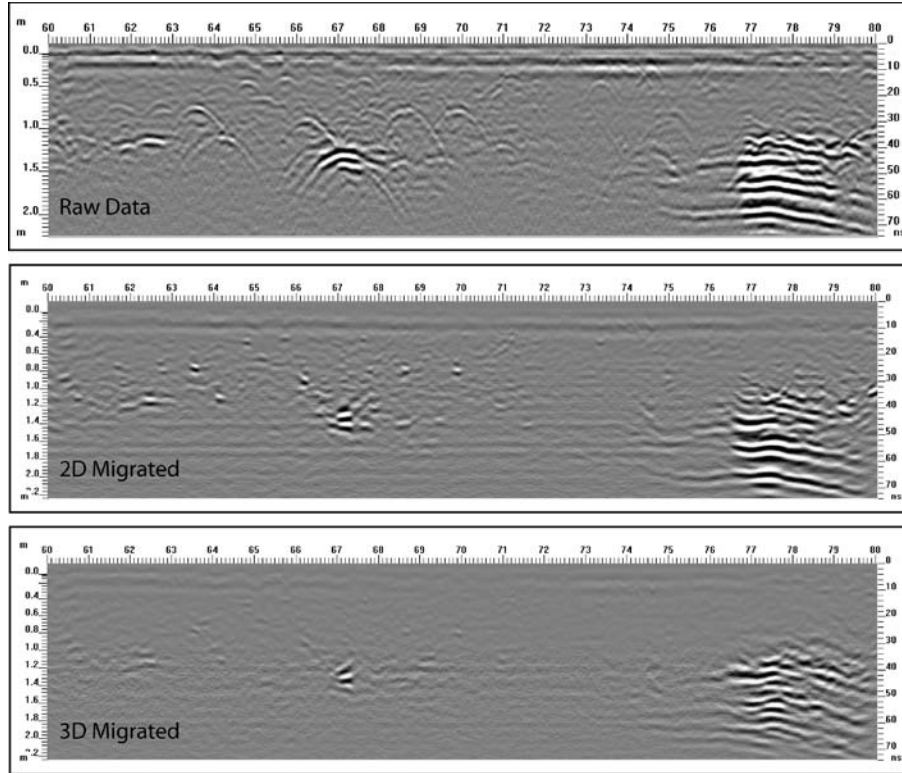


Figure 5: Comparison of unmigrated (raw), 2D migrated, and 3D migrated GPR profiles from Grid 0, showing numerous diffraction hyperbolae, including one high-amplitude reflection at $x = 67$ m, $z = 1.3$ m. Note also the strong sub-parallel feature from $x = 76$ -80 m. 2D migration is not adequate at collapsing all energy, thereby necessitating the use of 3D migration. Vertical exaggeration = 2x.

Imágenes geofísicas tridimensionales de las subsuperficies geológicas y de las características antropogénicas en Los Naranjos, Honduras utilizando radar de penetración de tierra y detectores magnéticos

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Datos tridimensionales de radar de penetración de tierra (GPR, por sus siglas en inglés) y de detectores magnéticos fueron adquiridos en el sitio arqueológico de Los Naranjos, Honduras durante los veranos de 2003 y 2007. Los Naranjos, situado en la orilla noroeste del lago Yojoa, es uno de los primeros asentamientos en Mesoamérica. El sitio fue ocupado continuamente entre el Formativo Temprano y el Postclásico Temprano (sobre 1100 a.C. – 1200 d.C.). Las metas de estos estudios geofísicos eran aumentar los alcances de las limitadas excavaciones arqueológicas del programa conjunto entre la Universidad de Cornell y la Universidad de California en Berkeley, proporcionando una imagen tridimensional detallada del subsuelo en el Grupo Principal, en donde se encuentran algunas de las estructuras terrestres más grandes y que fueron construidas a los principios de la formación del lugar. Estos resultados permiten entender como las comunidades del Periodo Formativo se desarrollaron alrededor estas monumentales estructuras.

GPR eficazmente delineó la estratificación del Cuaternario y localizó e identificó las características del subsuelo. La profundidad de la penetración fue variable, generalmente excelente (5m) pero pobre (0.5 m) algunos lugares. Se reconstruye la historia geológica de la zona basado en evidencia de discordancias, la patrón de onlap de estratos sobre discordancias, y fallas. Numerosas hipérbolas de la difracción y anomalías en la amplitud sugieren la existencia de artefactos arqueológicos enterrados en el lugar. La correlación entre las anomalías magnéticas y las imágenes obtenidas con GPR implican una gama de litologías y de composiciones del artefacto. Los resultados de GPR han sido útiles en la distinción natural de las características antropogénicas en la superficie y son consistentes con la composición arcillosa de los centros de las estructuras monumentales. A pesar de que la técnica del GPR en otros sitios en Honduras hayan tenido un éxito limitado, el trabajo en Los Naranjos muestra un considerable potencial para esta tecnología en la definición del entorno geológico y del trazado de las estructuras antropogénicas enterradas.

Hyperspectral remote sensing in archaeology. Experiences and application in Central American sites

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Since their early stages, remote sensing techniques have been applied to archaeological studies. A remote sensing instrument measures the electromagnetic radiation coming from the study target; this radiation being either reflected sunlight, thermally emitted radiance or (in so-called active systems) energy sent by the instrument itself (microwaves in a RADAR or a laser beam in a LIDAR). A remote sensing system is labeled hyperspectral if the registered radiation is split in a large number (typically over 40), narrow (typically 10 to 20 nm), contiguous discrete wavelengths intervals ("bands"), and so different measurements on the same target are available in a 3D image, two spatial and one spectral. The high spatial resolution, well suited to the scale required, coupled with the discriminant power of multi-wavelength information, make it potentially valuable for detection of spectral anomalies as evidence of buried or semi-buried features. Other traditional parameters in remote sensing, such as, for instance, specific humidity, vegetation or thermal conditions, allow global analyses of natural and historical processes. However, cost limited for many years the use of airborne remote sensing images other than aerial photography, and few works have been published using hyperspectral data as a support to archaeology. This communication describes the characteristics of hyperspectral technology and the different application methods in order to show how to use this type of data to retrieve valuable archaeological information. The article presents several case studies in Spain using hyperspectral techniques in archaeological research. The benefits and limits, and the potential application of hyperspectral remote sensing in archaeological sites of Central America are evaluated.

Teledetección hiperespectral en arqueología. Experiencias y aplicación en yacimientos Centroamericanos

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Desde sus primeros tiempos las técnicas de teledetección han sido utilizadas en aplicaciones arqueológicas. Un instrumento de teledetección mide la radiación electromagnética procedente del objeto de estudio, radiación reflejada bien de la luz solar, térmica o radiancia emitida (en los llamados sistemas activos), bien la reflejada como respuesta al envío de la energía por el propio instrumento (microondas en un sensor RADAR o un haz de luz láser en un LIDAR). Los sensores denominados hiperespectrales son sistemas activos, que registran la radiación dividiéndola en un gran número (típicamente mayor de 100), estrechos (típicamente entre 10 y 20 nm) y contiguos intervalos discretos de longitud de onda ("bandas"), en diferentes mediciones sobre un mismo objeto formando una imagen tridimensional, dos dimensiones espaciales y una espectral. La alta resolución espacial, bien adaptada a la escala necesaria, junto con el poder discriminante de la información espectral multionda, hace de esta técnica potencialmente valiosa para la detección de anomalías espectrales como indicios de rasgos arqueológicos enterrados o semienterrados. Otros parámetros tradicionales en teledetección, como humedad específica, estado de la vegetación o condiciones térmicas, permiten análisis globales de procesos naturales e históricos. Sin embargo, los costes asociados, han limitado durante muchos años el uso de imágenes de sensores aeroportados distintas a las de fotografía aérea y han sido pocos los trabajos publicados utilizando datos hiperespectrales como apoyo a la arqueología.

En la presente comunicación se describen las características de la tecnología hiperespectral así como los diferentes métodos de aplicación a efectos de valorar la obtención de información arqueológica a partir de ellos. Se presentan varios casos de estudio en España sobre el uso de técnicas hiperespectrales en investigación arqueológica. Se exponen los beneficios y límites, y la aplicación potencial de teledetección hiperespectral en yacimientos arqueológicos centroamericanos.

A Multi-Resolution, Multi-Source 3D Model and Database of Temple 22 at Copan

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This paper presents a reality-based, multi-resolution, multi-source, remote-sensing project to reconstruct an eighth-century Maya temple at Copan: Temple 22, on the East Court of Copan's Acropolis. This international, interdisciplinary project will reconstruct the temple digitally for research and public education, and will work with IHAH to develop a prototype of a WEB-GIS database that can store the data created from this project (and others) to assist archaeologists and cultural heritage managers to study and conserve the architecture of this ancient city.

Ancient Maya architecture of Mexico and Central America is the best-preserved, indigenous architectural tradition of the ancient Americas, and lasted for almost two-thousand years (600 B.C. – A.D. 1521). Copán—on the southern frontier of the Maya world—is famous for the high-relief stone sculpture found on its temples. Excavations have shown that the kingdom had a dynasty of sixteen kings that ruled over five centuries (AD 427-820). The four-meter-high portraits of Copán's thirteenth ruler—King Waxaklajuun U'baah K'awiil (reigned AD 695-738) give a sense of this kingdom's artistic accomplishments. This king commissioned the temple that is the subject of this project.

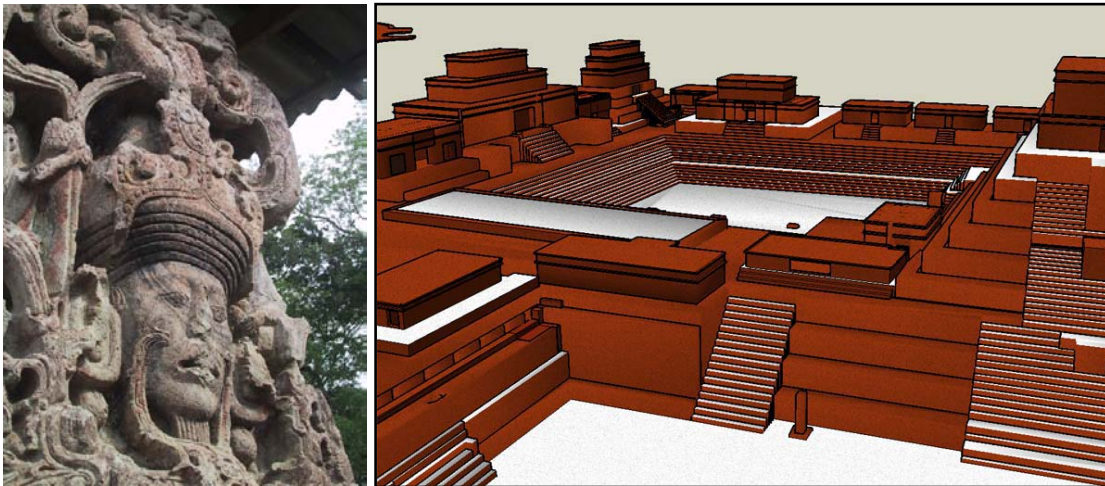


Figure 1. Portrait of Ruler 13 (Stela B, Copan) and Sketch-Up reconstruction of Copan's East Court and with Temple 22 to the left (Sketch-Up reconstruction -in progress- by Heather Richards)

Crowning the acropolis at Copan, it is called “Temple 22” by archaeologists, but can be considered the “Parthenon of the Maya world” because its remarkable sculpture is in museums around the world. The most famous of these is the Maya Maize God, now at the British Museum.



Figure 2: Maize God sculpture from Temple 22, Copan. British Museum collection, London

Temple 22 was a daring experiment in masonry architecture, but once the plaster and paint wore off, its upper facades and sculpture collapsed. Today only the first story remains and it is hard for visitors to imagine the glory of this ancient temple. Fortunately, archaeologists have been working since 1885 to excavate and conserve this temple and determine its original appearance. Since 1998 von Schwerin has worked with the Harvard University, the Copan Mosaics Project and IHAH to lead the conservation and analysis of the Temple 22 façade sculpture and is now prepared to attempt a digital reconstruction of the temple's facades.

This international project between architectural historians, archaeologists, and computer experts at the University of New Mexico, ETH Zurich, the German Archaeological Institute, the F. B. Kessler Foundation, the University of Merced, and the Honduran Institute of Anthropology and History will reconstruct this “Temple of the Maize God” and set it within its ancient context. The building, its sculpture, and sections of the ancient city will be recorded with aerial and terrestrial photogrammetry, structured-light and laser-scanning. The team will use this data to develop and test a 3D digital reconstruction of the temple in a VR environment and connect this to a GIS database intended for use for both research and public education.

Not since the Temple of the Warriors at Chichen Itza, and the House of the Governors at Uxmal were reconstructed in the 1920s and 1930s, has Maya archaeology had such a large sample of preserved sculpture from which to reconstruct a highly-complex, temple façade. However, since the 1960s, UNESCO has frowned upon the reconstruction of temples at archaeological sites—promoting “consolidation” instead. While this prevents tourists from being deluded by “imaginary” reconstructions, it presents a dilemma for archaeologists and site managers who want to give the public a sense of the complexity and beauty of ancient Maya architecture. Remote sensing provides a way to offer accurate, scaled models of Maya temples for analysis and education.

A Multi-Resolution, Multi-Source 3D Model and Database of Temple 22 at Copan

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Exploring the Multi-Functionality of Geographic Information Systems: Data, Analysis and 3D Visualization at Ancient Copán, Honduras

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Figure 1: Geographic Information Systems (GIS) 3D Reconstruction of Copán Valley, Honduras

Geographic Information Systems (GIS) offer many advantages to storing, managing, creating, analyzing and visualizing spatial data. The goal of this presentation is to discuss some of the ways in which archaeologists and cultural resource managers can make use of the multi-functionality of GIS. The discussion is organized into three parts.

The first part provides an overview of the Geographic Information System (GIS) that the author developed to carry out an access and visibility study of ancient settlement at Copán, Honduras. She will briefly discuss the types of data – attribute and spatial – in the GIS and the processes used to create them. The Environmental Science Research Institute's (ESRI) GIS software package ArcGIS 9.1 was used to collect, store, create, edit, and analyze the GIS data.

The second part focuses on the analytical capabilities of GIS. The emphasis will be on how the GIS was used to provide an innovative method to measure access and visibility in order to study social connectivity among Copán's different social groups. Most studies on access and visibility in the Maya region have been limited to small-scale analyses typically focusing on individual buildings, freestanding monuments or architectural complexes. The author argues that the emphasis on small areas is due to the types of data and methods that these studies employed. With the advent of new GIS technology, archaeologists can now begin to study access and visibility at larger scales taking into account many more features in the landscape such as topography, hydrology, sacbeob (causeways), monumental buildings, freestanding monuments, elite complexes, and commoner households. Such analyses are possible because of the ability of GIS to create and analyze raster datasets – rectangular matrices of cells, or pixels. The advantage of raster datasets are that they form a continuous surface on which to carry out GIS-modeling and three-dimensional visualization. In this study, an Urban Digital Elevation Model serves as the base file from which to make access and visibility measurements.

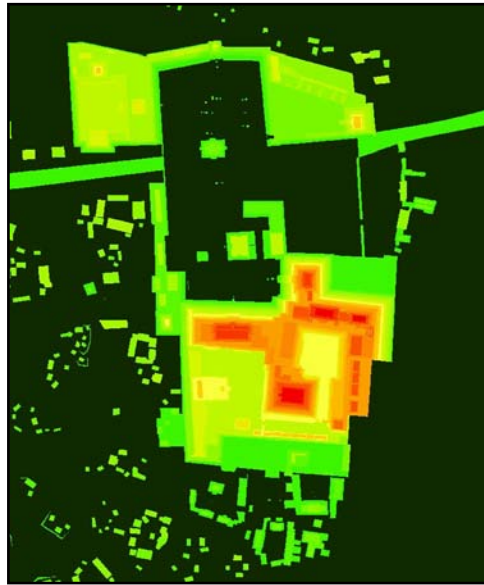
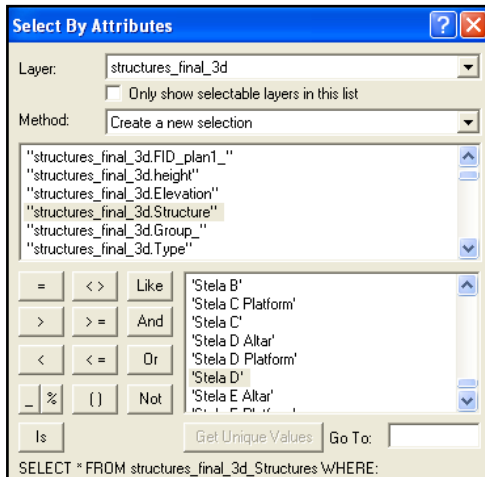


Figure 2: of Attributes in Geographic Information System (GIS) for Copán, Honduras (left). Urban Digital Elevation Model of Principal Group, Copán, Honduras (right).

The third part shows how the GIS data can easily be used to create course-grained 3D models of archaeological sites – in this case using Google SketchUp – that can be used for teaching and public outreach. Although the SketchUp model for ancient Copán is still in its formative stages, several areas are completed including the Principal Group and parts of the suburbs of Las Sepulturas and El Bosque – the 3D model for these areas will be shown.

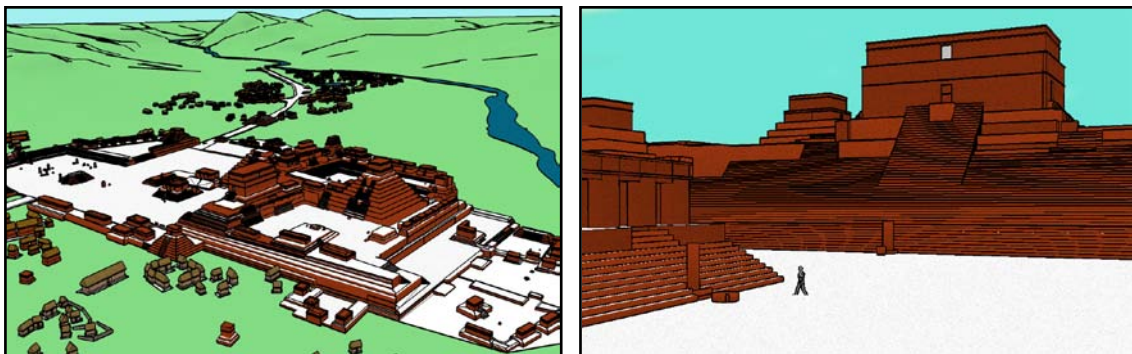


Figure 4: Google SketchUp 3D Model of Ancient Copán, Honduras

Exploring the Multi-Functionality of Geographic Information Systems: Data, Analysis and 3D Visualization at Ancient Copán, Honduras

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**Conservation, Science, and Public Education:
3D modeling and Photogrammetry beyond Copan's Principal Group**

Allan Maca¹, Clement Valla²

¹Colgate University, USA

²Rhode Island School of Design, USA

This paper discusses the goals, implications, limitations, and technologies involved in our recent 3D computer modeling of sites and features in the Copan Valley. We discuss the digital modeling of major architectural groups in the northern foothills (Group 9J-5 in Comdero) and in El Bosque (Group 11K-6).

In our discussion we will also discuss the modeling and photogrammetry employed in studying Tomb 1 from Group 11K-6 and will show clips from a documentary film we wrote and produced in 2006-7.

**Conservation, Science, and Public Education:
3D modeling and Photogrammetry beyond Copan's Principal Group**

Allan Maca¹, Clement Valla²

¹Colgate University, USA

²Rhode Island School of Design, USA

3D GIS and Advanced Databases: An Example from Pompeii

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In archaeology the systematic and well-judged use of 3D information for documentation and conservation is a relatively recent innovation, not yet applied on a regular basis as considered too expensive, not really useful and difficult to be linked to classical 2D information. The reason of this lack can be attributed to the perceived 'high cost' of 3D, the difficulties in achieving good 3D models, the perception that this is an 'optional' process of interpretation (an additional 'aesthetic' factor), the difficulty of integrating 3D worlds with other 2D data and documentation and the episodic use of 3D models for scientific analysis. Nowadays the most common techniques used for 3D documentation are based on image or range data. Both approaches, often combined, have their own advantages and disadvantages and generally the choice between them is made according to the budget, project size, required degree of detail, surface characteristics, objectives and experience of the working team. Once a 3D digital model is produced, many further products and studies can be led. Besides visualization, VR, physical replicas, the recovered digital 3D data can be used to rebuild the original architectural layout of archaeological sites and / or program intervention policies. Furthermore 3D geometry can be segmented, classified and linked to databases.

In this contribution we present a methodology developed to assist the superintendence of archaeological excavations and heritage sites in the digital reconstruction, classification, management and visualization of finds and monuments using advance 3D repositories. The problem required a solution able to provide segmented and classified 3D models which could be interfaced and linked to archaeological databases and GIS. The reported approach has been realized as general as possible and tested on different archaeological objects. The method (i) produces reality-based photo-realistic 3D models, (ii) classifies them in layers and (iii) assigns to each element archaeological and architectural information beside the already known 3D geometric properties. Therefore the recovered 3D structures are broken down into their component parts (e.g. capital, shaft, base, etc.) following basic libraries of geometric primitives and then associated to information extracted from existing databases. Each part of the find or monument is then connected to series of information created to ease the retrieval process (on a web-based interface) in a semantics-based context. The goal of the methodology is also to improve the retrieval of 3D objects and related information within a repository by annotating each shape not only as a whole, but also in terms of its meaningful subparts, their attributes and their relations. Therefore the possibility to semantically annotate shape parts may have a relevant impact in several domains, like archaeology.



Figure 1: Web interface of the advance 3D archaeological repository

3D GIS y bases de datos avanzada: un ejemplo de Pompei

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En arqueología el uso sistemático de la información en 3D para la documentación y la conservación es una innovación relativamente reciente, no todavía aplicada regularmente porque considera demasiado cara, no realmente útil y difícil de vincular a la información clásica 2D. La razón de esta falta puede atribuirse a la percepción de «alto coste» del 3D, las dificultades en la adquisición de buenos modelos en 3D, la percepción que se trata de un proceso “opcional” de interpretación (un factor “estético” accesorio), la dificultad de la integración de los mundos 3D con otros datos en 2D y la documentación y el uso episódico de modelos 3D para el análisis científico. Hoy las técnicas más comunes utilizadas para la documentación en 3D se basan sobre imágenes o datos láser. Ambos métodos, a menudo combinados, tienen sus propias ventajas y desventajas y, en general, la elección entre ellos se realiza de acuerdo con el budget y dimensión del proyecto, el grado de detalle, las características de la superficie, los objetivos y la experiencia del equipo de trabajo. Una vez que un modelo digital 3D está preparado, muchos más productos y estudios pueden ser conducidos. Además de la visualización, realidad virtual, réplicas físicas, los datos digitales 3D se pueden utilizar para reconstruir el original diseño arquitectónico de los sitios arqueológicos y / o para programar las políticas de intervención. Además la geometría 3D puede ser segmentada, clasificada y vinculada a bases de datos.

En esto coloquio se presenta una metodología desarrollada para ayudar la supervisión de las excavaciones arqueológicas y de los sitios del patrimonio en la reconstrucción digital, clasificación, gestión y visualización de los restos y monumentos, usando avanzados instrumentos 3D. El problema requiere una solución capaz de proporcionar modelos 3D segmentados y clasificados que pueden ser interconectados y vinculados a bases de datos arqueológicos y los SIG. El método presentado se ha realizado lo más general posible y probado en diferentes objetos arqueológicos. El método (i) produce modelos 3D foto-realistas, (ii) los clasifica en layers y (iii) asigna a cada elemento una información arqueológica y arquitectónica de junto a la ya conocidas propiedades geométricas 3D. Entonces las estructuras 3D modeladas son divididas en sus componentes (por ejemplo, el capital, columnas, base, etc.), segundo una biblioteca básica de primitivas geométricas, y asociadas a la información extraída de bases de datos existentes. Cada parte del monumento u objeto es conectada a unas series de información generadas para facilitar el proceso de recuperación (en una interfaz Web) en un contexto semántico. El objetivo de la metodología es también de mejorar la recuperación de objetos 3D e información relacionada en un repositorio, con la anotación de cada forma no sólo en su conjunto, sino también en términos de su sub-partes, sus atributos y sus relaciones. Entonces la posibilidad de anotar semánticamente la forma de las partes puede tener un impacto relevante en diversos ámbitos, como la arqueología.

GIS Database in Archaeology and Cultural Heritage: Documentation and Archaeological Analysis of the Geoglyphs of Palpa, Peru

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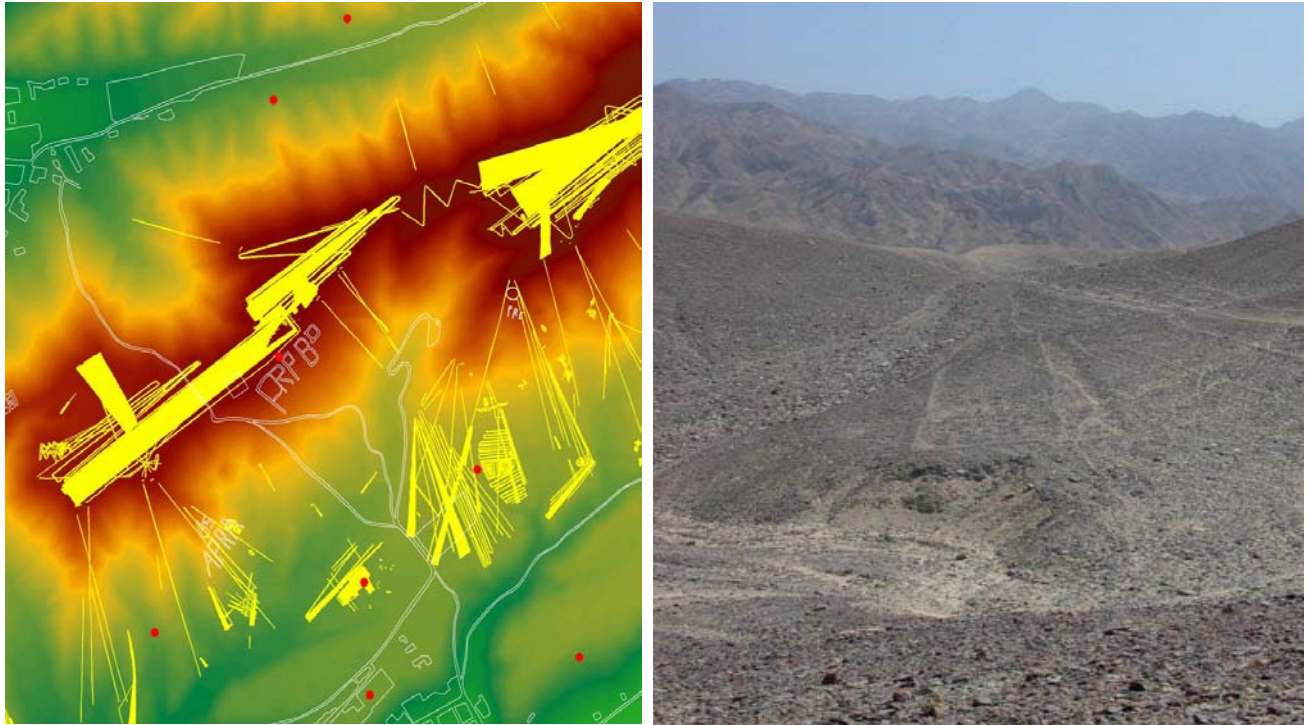
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The Nasca-Palpa Project in southern Peru, started in 1996 and coordinated by the German Archaeological Institute, Bonn, Germany, involved many institutions from different disciplines. In this project we studied the cultural and environmental history of the northern part of the Nasca region around the modern town of Palpa, about 400 km southeast of Lima, from the earliest human occupation to the Spanish conquest. Special attention was paid to the Paracas and Nasca period (800 BC to AD 650) during which the famous geoglyphs, also known as “Nasca lines”, were built and used. The Institute of Geodesy and Photogrammetry at ETH Zurich contributed to the project through the acquisition and processing of spatial data, mainly by means of photogrammetry and laser scanning. At the Copan workshop we will focus on the 3D documentation and analysis of the geoglyphs, showing how important new insights into their function and meaning were gained thanks to close interdisciplinary cooperation and the consistent application of new technologies to archaeological research.

After introducing the archaeological problems and the research activities accomplished within the framework of our project, we will focus on the generation of the 3D models and the GIS database developed for the purpose of data management and analysis of the geoglyphs in the Palpa area in order to study them within their cultural and natural context. The workflow developed for this purpose allowed us to generate a database containing comprehensive spatial and semantic data on the geoglyphs based on aerial images and archaeological fieldwork. We will explain the data structure and its importance for the spatial analysis of the geoglyphs by means of GIS-based and statistical methods. Furthermore, we will report on our experiences concerning the software employed, especially GIS and database software products. In this context, we will also discuss the general advantages and disadvantages of current GIS and database software and give an outlook on future developments, such as 3D GIS and the functionality of spatial databases.

Finally, we will give a brief overview of the results of our analyses of spatial relations of the geoglyphs that may serve as useful examples for other archaeological projects. These analyses included visibility studies, investigation of geoglyph orientation and straightness as well as queries on the semantic data.



*Figure 1: Left: Geoglyphs on the Cresta de Sacramento represented by polygons (yellow).
Right: View along a geoglyph near Palpa.*

Base de datos de SIG en Arqueología y Patrimonio Cultural: Documentación y Análisis arqueológico de los Geoglifos de Palpa, Perú

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El proyecto Nazca-Palpa, en el sur de Perú, comenzó en 1996 y coordinado por el Instituto Arqueológico Alemán, Bonn, Alemania, que participan muchas instituciones de diferentes disciplinas. En este proyecto se estudia la historia cultural y ambiental de la parte norte de la región de Nazca en la moderna ciudad de Palpa, a unos 400 km al sureste de Lima, a partir de la primera ocupación humana de la conquista española. Se presta especial atención a los período de Paracas y Nazca (800 AC a 650 DC) durante el cual los famosos geoglifos, también conocido como "líneas de Nazca", fueron construidos y utilizados. El Instituto de Geodesia y Fotogrametría de la ETH Zúrich han contribuido al proyecto a través de la adquisición y el tratamiento de los datos espaciales, principalmente por medio de fotogrametría y láser de barrido. En el taller de Copán nos centraremos en la documentación 3D y el análisis de los geoglifos, que muestra la importancia de las nuevas ideas sobre su función y significado se obtuvo gracias a la estrecha cooperación interdisciplinaria y la aplicación coherente de las nuevas tecnologías a la investigación arqueológica.

Después de la introducción de los problemas arqueológicos y las actividades de investigación realizada en el marco de nuestro proyecto, nos centraremos en la generación de los modelos 3D y de la base de datos GIS desarrollada con el propósito de la gestión de datos y el análisis de los geoglifos de Palpa en el área con el fin de estudio dentro de su contexto cultural y natural. El flujo de trabajo desarrollado para este propósito que nos ha permitido generar una amplia base de datos que contiene los datos espaciales y semántica en los geoglifos sobre la base de imágenes aéreas y trabajo de campo arqueológico. Vamos a explicar la estructura de datos y su importancia para el análisis espacial de los geoglifos por medio de SIG y basado en métodos estadísticos. Además, presentará un informe sobre nuestras experiencias en relación con el software empleado, sobre todo sistemas de información geográfica y base de datos de productos de software. En este contexto, también vamos a debatir las grandes ventajas y desventajas de los actuales sistemas de información geográfica y software de bases de datos y dar una perspectiva sobre la evolución futura, como el SIG 3D y la funcionalidad de bases de datos espaciales.

Por último, daremos una breve reseña de los resultados de nuestro análisis de las relaciones espaciales de los geoglifos que pueden servir como ejemplos útiles para otros proyectos arqueológicos. Estos análisis incluyen estudios de visibilidad, la investigación de orientación geoglifos y rectitud, así como consultas sobre la semántica de datos.

Virtual Rome: an open source 3D web

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Virtual Rome is an Open Source web VR project, based on geospecific data, 3d models and multimedia contents, with front-end (VR webGIS) and back-end (VR webLAB) on line solutions, for the interpretation, reconstruction and 3d exploration of the archaeological and potential landscape of ancient Rome. The purpose is the creation of a three-dimensional on line 3d environment, embedded into a web-browser able to represent the diachronic evolution of the ancient Roman landscape.

Virtual Rome: un web 3D con código abierto

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**New challenge for IHAH:
Implementing new tools for decision making
(needs and opportunities for access and exchange of information)**

Ricardo Rodriguez

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This paper focuses on explaining some of the key issues needed to make before starting construction of a very powerful tool for decision making as it is a Geographic Information System, the reason for the focus of this paper is simply because they are not taken into account due to many factors such as the lack of a team where everyone makes their contribution in their area of expertise and many institutions have fallen into the trap of wanting to implement tools impossible to handle by one person or without the platform, protocols and standards for proper implementation, publication and dissemination. The paper focuses on 6 key points raised: 1.- Spatial Data Infrastructure, 2.- Policies on use of and access to information, support 3.- Conventions and exchange of information 4.- Team multi-disciplinary and multi-institutional, 5.- Documentation, and 6.-scale coverage available and used.

**Nuevo desafío para el IHAH:
Implementación de nuevas herramientas para la toma de decisiones
(necesidades y oportunidades para el acceso e intercambio de
información)**

Ricardo Rodriguez

Instituto Hondureño de Antropología e Historia (IHAH)
Honduras

Este documento se enfoca en explicar algunos de los temas fundamentales y necesarios antes de iniciar a efectuar la construcción de una herramienta tan poderosa para la toma de decisiones como lo es un Sistema de Información Geográfico, la razón de enfocarme en los puntos de este documento es sencillamente porque no son tomados en cuenta debido a muchos factores como ser la falta de un equipo multidisciplinario donde cada uno realiza sus aportes en su área de especialización y muchas instituciones han caído en el error de querer implementar herramientas imposibles de manejar por una sola persona o sin la plataforma, protocolos y normas adecuadas para una correcta implementación, publicación y divulgación. El documento se enfoca en plantear 6 puntos importantes: 1.- Infraestructura de Datos Espaciales, 2.- Políticas de uso y acceso a la información, 3.- Convenios de apoyo e intercambio de información, 4.- Equipos de trabajo multi-disciplinarios y multi-institucionales, 5.- Documentación, y 6.- Coberturas disponibles y escalas utilizadas.

**Mapa topografico del Grupo Residencial Norte (Grupos 9L-22 y 9L-23) de Copan:
Creando un modelo digital de terreno con un modelo volumetrico de las estructuras.**

S. Nakamura, F. Castaneda and K. Imaizumi

(abstract not yet submitted)

Maya archaeology as an application field of Virtual Reality Technology.

by Toppan Co. Limited. and S. Nakamura

(abstract not yet submitted)

Biographies of Speakers in Speaking Order

Darío A. Euraque

Darío A. Euraque was born in Tegucigalpa, Honduras, and is the current Director of the Honduran Institute of Anthropology and History. Euraque graduated in 1982 with a BA in European History and Philosophy from Marquette University in Milwaukee, Wisconsin. Between 1982 and 1990 he attended the University of Wisconsin, Madison, where he received an MA in Ibero-American Studies, an MA in History and a PhD in Latin American History (focus: Central American history). In 1990, Euraque began teaching at Trinity College in Hartford, Connecticut. At Trinity he taught at all levels, from introductory courses on Latin America and the Caribbean to upper division courses on race, ethnicity, state formation, and the comparative history of gender and sexuality. He simultaneously published a number of books on modern Honduran history, in English and Spanish. He has published numerous academic articles and book reviews. He has been a consultant to Honduran governments, various United Nations projects in Honduras, and to the UNESCO. He has lectured in many countries around the world on Honduran history, including Spain, Italy, Japan, England, Mexico, France, Colombia, Chile, Argentina and all countries in Central America. He is scheduled to serve as the Director of the Honduran Institute of Anthropology and History until January of 2010.

Jennifer von Schwerin

Jennifer von Schwerin is Assistant Professor in the Department of Art and Art History and the Department of Architecture and Planning at the University of New Mexico, and Principal Investigator of the Temple 22 Façade Sculpture Analysis Project, a sub-project of the Copan Mosaics Project. Funded by a Research Fellowship from the Alexander von Humboldt Foundation, she currently is a Visiting Researcher at the German Archaeological Institute, Bonn and the Institute for Cultural Anthropology of the Americas at the University of Bonn. Her research is devoted to Maya art and architecture, the architecture of the ancient Americas, critical theory, and cultural heritage management, and she is currently completing a book manuscript titled "Maya Temple Architecture and Ritual: The Temple of the Maize God at Copan." Dr. von Schwerin has received fellowships from Fulbright, the Alexander von Humboldt Foundation, the Whiting Foundation and The Metropolitan Museum of Art. She has published in *Current Anthropology*, *Yaxkin*, the *Journal of Anthropological Research*, and has presented her research at meetings of the Society for American Archaeology, the College Art Association, and the Society for Architectural Historians.

Armin Gruen

Prof. Dr. Armin Gruen has been Professor and Head of the Chair of Photogrammetry at the Institute of Geodesy and Photogrammetry, Federal Institute of Technology (ETH) Zurich, Switzerland since 1984. Prof. Gruen has held lecturing and research assignments at the University of Armed Forces, Munich, Germany, Helsinki University of Technology, Finland, Università degli Studi di Firenze, Italy, Stanford Research Institute, Menlo Park, USA, Department of Geodesy, Technical University Delft, Netherlands, Asian Institute of Technology (AIT), Bangkok, Thailand, Department of Geomatics, University of Melbourne, Australia, Center for Space and Remote Sensing Research, National Central University, Jhongli City, Taiwan and SCUODO program of the Politecnico Torino, Italy. He has lectured at the University level since 1969, with photogrammetry and remote sensing as major subjects, and surveying, cartography and adjustment calculus as minor subjects. His cultural heritage projects include: the Great Buddhas of Bamiyan, Afghanistan, Nasca geoglyphs, Tucume, Machu Picchu, Bayon Temple, Angkor, Mount Everest, Ayers Rock and many more (please visit the homepage www.photogrammetry.ethz.ch under PROJECTS). He has published more than 375 articles and

papers and is Editor and Co-editor of 21 books and Conference Proceedings. He has organized and co-organized/co-chaired over thirty international conferences and he has served as a consultant to various government agencies, system manufacturers and engineering firms in Germany, Japan, Switzerland, USA and other countries. He is co-founder of CyberCity AG, Zurich, Switzerland. He served as the President of ISPRS (International Society of Photogrammetry and Remote Sensing) Commission V. He is currently Chairman of the ISPRS International Scientific Advisory Committee (ISAC), International Member of the Fourth Academic Committee of the State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing (LIESMARS), Wuhan University, China, and Member of the Executive Board of the Digital Earth Society.

Fabio Remondino

Fabio Remondino is since 1999 a scientific researcher at the Institute of Photogrammetry and Remote Sensing of ETH Zurich, Switzerland. Now he is also a scientific researcher at the Centre for Scientific and Technological Research of the B. Kessler Foundation in Trento, Italy, where he leads the 3D Optical Metrology Group. He received his master's degree in environmental engineering at Polytechnic of Milan, Italy, and a Ph.D. in image-based modeling from ETH Zurich, Switzerland. He is the chairman of the Working Group on "image- and range-based 3D modeling" for the International Society of Photogrammetry and Remote Sensing (ISPRS). His main interests and areas of work are the digital documentation and 3D modeling of large and complex heritage areas and the automation of the different phases within the 3D modeling pipeline. He worked at the 3D digital reconstruction of the Pompeii Forum (Italy), the Acropolis of Athens (Greece), the Great Inscription of Gortyna (Crete), the Big Buddha of Bamiyan (Afghanistan) and Machu Picchu (Peru). He authored more than 60 scientific publications in international conferences and journals. He organized different conferences and summer schools related to 3D modeling in the Cultural Heritage field and he won 5 awards for best paper presented at scientific conferences or on journal.

Henri Eisenbeiss

Henri Eisenbeiss is Lecturer and Teaching and Research Assistant at the Institute of Geodesy and Photogrammetry, ETH Zurich. He is specialist in UAV Photogrammetry. Henri Eisenbeiss worked in several projects, which are related to Photogrammetry, Remote Sensing, Archaeology, Geology and Agriculture. His research focus is on the automation of the photogrammetric workflow by using UAVs as data acquisition platform for civilian applications. Furthermore he is interested in processing of high-resolution images, 3D Modeling and Visualization. Since 2008, he is Co-Chair of the ISPRS ICWG I/V: UVS for Mapping and Monitoring Applications.

Maurizio Forte

Maurizio Forte, PhD, is full professor of World Heritage at the University of California, Merced and Professor of "Virtual Environments for Cultural Heritage" in the "Master of Science in Communication Technology-Enhanced Communication for Cultural Heritage" (TEC-CH) program at the University of Lugano. At the University of California he teaches "World Heritage" and "Reconstructing Ancient Words" (a part of these courses is in Second Life); he is also director of the Virtual Heritage Lab. Since 2008, he has served as an independent expert for the European Community. He was Chief of Research at CNR (Italian National Research Council) of "Virtual Heritage: integrated digital technologies for knowledge and communication of cultural heritage through virtual reality systems" (2005-2007) and director of the Virtual Heritage Lab (2000-2007). He was Senior Scientist at CNR's Institute for Technologies Applied to the Cultural Heritage (ITABC), Vice-President of the international non-profit Virtual Heritage Network. He received his bachelor's degree in Ancient History (archaeology), and a Diploma of specialization in Archaeology, from the University of Bologna, and his PhD in Archaeology from

the University of Rome “La Sapienza”. He has coordinated archaeological fieldwork and research projects in Italy as well as in Ethiopia, Egypt, Syria, Kazakhstan, Peru, China, Oman, and Mexico. He was author and scientific director of the first two public virtual museums in Italy, the Virtual Museum of the Scrovegni Chapel in Padua (2003) and the Virtual Museum of the Ancient via Flaminia in Rome (2008 at the National Roman Museum); the second one is the first virtual museum based on a collaborative environment in Europe. He is editor and author of several books including “Virtual Archaeology” (1996), Virtual Reality in Archaeology (2000), “Sistemi Informativi Geografici, GIS, in Archeologia”(2002) “From Space to Place” (2006) and he has written around 200 scientific papers. Topics of his activity are: virtual reality, cyber-archaeology, spatial technologies, 3D documentation, virtual reconstruction of archaeological landscapes and epistemology of the virtual. He was winner of the “Best paper award for the cultural merit” at the VSMM conference (2002), “Creative and digital culture” and of the E-content Award, 1st prize, category e-learning (2005).

Barbara W. Fash

Barbara W. Fash is Director of the Corpus of Maya Hieroglyphic Inscriptions (CMHI) at the Peabody Museum, Harvard University. She is an artist and museum professional (M.A., Harvard University, Museums Studies 2007) who has worked at the Maya site of Copan, Honduras recording, studying and conserving the sculpture carvings, with a special focus on the Hieroglyphic Stairway, since 1997. Her projects include, Co-Director, Copan Mosaics Project (1985–present); Curator and exhibition director, Copan Sculpture Museum (1993–1996); Honduras Director, Hieroglyphic Stairway Conservation Project (1997–2001); Director, Database Project for the Research Library and Archives at Copan's Regional Center for Archaeological Research (2000–2002). She curated the exhibitions, "Distinguished Casts; Curating Lost Monuments at the Peabody Museum," and “Fragile Memories: Archaeology and Community, Copan, Honduras, 1891-1900.” In addition to numerous scholarly articles, her publications include Precolumbian Water Management: Ideology, Ritual, and Power, (2006, with Lisa Lucero) and The Copan Sculpture Museum: Ancient Maya Artistry in Stucco and Stone (in press). Her illustrations appear in numerous books, including: W. L. Fash, Scribes, Warriors and Kings: The City of Copán and the Ancient Maya (1991, 2001); G. Willey, R. Leventhal, A. Demarest and W. Fash, Jr. Ceramics and Artifacts from the Copan Residential Zone (1994); C. F. Baudez, Maya Sculpture of Copan (1994). She was awarded the Hoja de Laurel de Oro by Honduras (2008) and currently directs projects to three-dimensionally scan the Hieroglyphic Stairway and publish additional CMHI volumes.

Tiffany Tchakirides

Tiffany Tchakirides received her B.A. degrees in Anthropology and Geology from Syracuse University in 1999. She received her M.A. degree in Anthropology from the University of Denver, where she began her training as an archaeological geophysicist using ground-penetrating radar (GPR). After completing her Master's degree, she worked for a GIS consulting firm. In 2004, she began her studies in Geophysics in the Department of Earth and Atmospheric Sciences at Cornell University. She has conducted shallow geophysical research at archaeological sites in Honduras, Mexico, China, and throughout Colorado and the western United States. For her Ph.D. dissertation research, Tiffany is analyzing ground-penetrating radar and magnetometry data collected at Los Naranjos and Puerto Escondido, Honduras.

Larry Brown

Larry Brown is the Sidney Kaufman Professor of Geophysics and the Chair of the Department of Earth and Atmospheric Sciences. Brown did his undergraduate studies at Georgia Institute of Technology in Physics and earned his Ph.D. from Cornell University in 1976. His primary research interest is application of multichannel seismic reflection methods to the exploration of

the continental lithosphere and to the investigation of deep tectonic processes. Current projects are underway on the northeastern Tibet Plateau, across the island of Taiwan, and on the volcanically active Caribbean island of Montserrat. In addition, his interests include application of ground-penetrating radar to archaeology and volcanostratigraphy.

Juan Gregorio Rejas Ayuga.

Juan Gregorio Rejas Ayuga is a researcher at the National Institute for Aerospace Technology (INTA) in Madrid, Spain, member since 1995 of the Department of Earth Observation, Remote Sensing and Atmosphere, involved in several research projects in airborne remote sensing for the European Community. He is collaborator of the Planetary Geology Laboratory of the Astrobiology Center (CAB) in Madrid. He is Assistant Professor in the Department of Morphology and Land Engineering of the Polytechnic University of Madrid (UPM). He is since 2001 professor in the “Master in Environmental Engineering and Water Management” at the EOI Business School, Madrid, professor in the MOGT Master at the Central American Astronomical Observatory of Suyapa (OACS/UNAH) of Tegucigalpa, Honduras, and professor in several summer schools at the University of Zaragoza and the University of Salamanca in Spain, about technologies and methods in physical anthropology and archaeology. He received his M.S. degree in Geodesy and Cartography Engineering from Alcala University. He is currently working for his Ph.D. degree in features extraction from hyperspectral data and real time mapping, at UPM. His experiences in projects in Cultural Heritage are the archaeological sites of Recópolis and Segeda, and others in Spain, San Lorenzo de El Escorial (National Spanish Heritage) in Madrid, rural areas of Oruro, Potosí, Sucre and Cochabamba in Bolivia and The Emirate of Al'Madam, in The United Arab Emirates. He is current involved in research projects in water resources, climate change, risk in human habitats and cultural heritage in Costa Rica and Honduras. He is co-founder and moderator of the Remote Sensing Group of the RedIRIS (Academic Spanish Network). He is member of the Remote Sensing Spanish Association (AET) and member of the research group “Cultural Heritage Management and New Technologies” at UPM. He authored more than 40 scientific publications in international conferences and journals.

Heather Richards-Rissetto

Heather Richards is a PhD Student in the Department of Anthropology at UNM. Her specialization is Maya Archaeology and Geospatial Technologies. In the course of her doctoral research on Socio-Semiotics and Space: Exploring Access and Visibility at the Ancient Maya Site of Copán, Honduras she developed a Geographic Information Systems (GIS) for Copán. This spatial database, comprised of vector and raster files, includes data on over 3,000 structures, freestanding monuments, hydrological features, causeways, contours, and Digital Elevation Models (DEM) of the natural and urban landscapes. In 2005 she worked with Dr. Jennifer von Schwerin to create a photogrammetric model of the East Court of the Acropolis at Copán. Recently, she was a PhD Fellow at the Latin American and Iberian Institute at UNM. She has taught several courses and given guest lectures on geospatial technologies including GIS, remote sensing, and Global Positioning Systems (GPS). She has published in edited volumes and several conference proceedings and presented her research at meetings of the Society for American Archaeology, Environmental Science Research Institute's International User Conference, American Society for Photogrammetry and Remote Sensing, International Society for Photogrammetry and Remote Sensing, Annual Water Resources Conference, and other professional venues.

Allan Maca

Allan Maca is from New York City and currently teaches at Colgate University in central New York state. He graduated from Kenyon College and received his PhD in Anthropology from Harvard University, specializing in Mesoamerican archaeology and the archaeology of Copan.

Allan's doctoral research focused on the northern foothills settlement of the Copan alluvial pocket. Since 2004 he has been director of the Copan Urban Planning Project, or El Proyecto Arqueológico para la Planificación de la Antigua Copán (PAPAC), which works to study the ancient city as a means to provide models for the protection of Copan's ruins against modern development and the increasing tide of looting. Thus, PAPAC combines both science and conservation in its approach to ancient and modern urbanism. Allan's other research interests include the historiography of American archaeology, method and theory, and ceramic analyses. The project currently focuses on mapping, excavations, and site protection in the El Bosque region of the Copan National Park.

Clement Valla

Clement Valla was born in Paris, France. He currently lives and works in Providence, RI. He received a BA in architecture from Columbia University, and is currently an MFA candidate at the Rhode Island School of Design. After working as an architect and designer in the USA, France, and China, Clement began using computers and digital technologies in interactive installations, websites, videos, sculptures, prints and paintings. In his work, Clement treats common objects, standard geometries, mundane site conditions, or market relationships as programmable systems. When these programs run their course, inherent contradictions and absurd situations result from the very structure of the system itself, producing unfamiliar artifacts and juxtapositions. Clement works within systems, applying a 'programmed brain' that pushes problem-solving logic to irrational ends.

Martin Sauerbier

Martin Sauerbier is a diploma engineer in geodesy and works as a research and teaching assistant at the Chair of Photogrammetry and Remote Sensing at the Federal Institute of Technology in Zurich (ETH Zurich) and as a researcher for the Department of Pre- and Protohistory of the University of Zurich. He obtained his degree in Geodesy at the University of Bonn in 1998 and currently works on his PhD thesis on GIS-based management and analysis of the geoglyphs in the Palpa region in Peru. His main research interests are in photogrammetric data acquisition and processing as well as geographic information systems for archaeological applications. He gathered experience in different interdisciplinary projects in spatial data acquisition, database modeling, GIS-based and statistical analyses of spatially related archaeological features.

Markus Reindel

Markus Reindel is an archaeologist at the German Archaeological Institute in Bonn. He is responsible for the Americas department of the Commission for Archaeology of Extra-European Cultures. He studied American Anthropology and Archaeology in Freiburg, Madrid and Bonn and earned his Ph. D. degree at the Institute of American Anthropology of the University of Bonn in 1991. He directed archaeological research projects in Peru (Monumental Adobe Architecture on the North Coast of Peru, 1988-1991), Ecuador (Proyecto Arqueológico La Cadena, Quevedo, 1992-1994), excavations in Mexico (Proyecto Arqueológico Xkipché, 1993-1997), and long term research projects in Peru (Proyecto Arqueológico Nasca-Palpa, since 1996). Since 2006 he is speaker of the Research Cluster "From Sedentariness to Complex Societies" of the German Archaeological Institute. In the Nasca-Palpa project he established cooperations with several disciplines like Geodesy and Photogrammetry, Geosciences, Archaeochronometry and Paleogenetics. From 2002 to 2007 he coordinated the interdisciplinary research project "Nasca – Development and Adaptation of Archaeometric Techniques for the Investigation of Cultural History" and since 2008 he is coordinating the joint research project "Andean Transect – Climatic Sensibility of the Relations of Pre-Columbian Man and Environment". Both projects are financed by the German Archaeological Institute and the German Federal Ministry for Education and Research.

His main interests in archaeological investigation are architectural history, settlement patterns, cultural history and geoarchaeology. Methodologically he has strong interests in archaeometry and interdisciplinary approaches to archaeological research strategies. In the framework of the Nasca-Palpa project he established collaborations especially with the Institute of Geodesy and Photogrammetry of the ETH Zurich for the development of 3D-Models on different levels: landscape, archaeological sites, architecture, big objects like petroglyphs and small objects like ceramic vessels. Recently he published the results of the interdisciplinary project "Nasca" with the title: "New Technologies for Archaeology. Multidisciplinary Investigations in Nasca and Palpa, Peru".

Karsten Lambers

Karsten Lambers is an archaeologist with the University of Konstanz, Germany. He obtained his MA in American Anthropology from the University of Bonn in 1998, and his PhD in Pre and Protohistory from the University of Zurich in 2004. From 2005 to 2007 he was a research associate at the Commission for Archaeology or Non-European Cultures, German Archaeological Institute (DAI-KAAK, Bonn). Since October 2008 he is a research fellow at the "Zukunftskolleg" (Institute of Advanced Studies), University of Konstanz. During his MA studies he conducted archaeological fieldwork in Germany, Mexico and Bolivia. From 1999 to 2007 he was engaged in the multidisciplinary Nasca-Palpa Project in southern Peru, where he investigated the geoglyphs of the Paracas and Nasca cultures in Palpa and Nasca in close cooperation with the Institute of Geodesy and Photogrammetry, ETH Zurich. His current research project investigates the use of high-resolution multispectral satellite imagery in archaeological prospection, with a focus on semi-automated extraction of archaeological features from imagery. His research interests cover the use of methods and technologies from geomatics and computer science in archaeology, landscape studies, and the prehispanic cultures of ancient Mesoamerica and the Andes.

Jesus Ricardo Rodriguez Rivera

El Lic. Rodríguez tiene más de 10 años de experiencia en las áreas de sistemas de información, teniendo como profesión principal Informática Administrativa. Su experiencia es específica en las áreas de Sistemas de Información Geográfica (SIG) en los que ha realizado trabajos de aplicación del sistema a proyectos de ordenamiento territorial, bases de datos, recursos naturales, medio ambiente, gestión municipal, servicios públicos, entre otros. El Lic. Rodríguez también cuenta con experiencia en el área dirección, gestión, participación y coordinación de instancias vinculadas a la implementación de sistemas de información, nacional, regional e internacionalmente a través de instituciones como la Comisión Centro Americana de Ambiente y Desarrollo (CCAD), proyectos como Sistema de Información Ambiental Mesoamericano (SIAM), Grupo de Observación de la Tierra Sistema de Sistemas (GEOSS), JICA, NASA entre otros.

**Workshop #2 of the
National Endowment for the Humanities, Digital Humanities Start-Up Project:**

**“3D GIS Database and Model of Maya Architecture
for Copan, Honduras”**

IGP, ETH Zurich

Thursday, May 28, 2009

Participants attending:

1. Henri Eisenbeiss, ETH Zurich
2. Armin Gruen, ETH Zurich
3. Uta Hassler, ETH Zurich (until 11.00)
4. Mario Hernandez, UNESCO
5. Hasso Hohmann, TU Graz
6. Karsten Lambers, University of Konstanz
7. Markus Reindel, KAAK, German Archaeological Institute
8. Fabio Remondino, FBK Trento
9. Martin Sauerbier, ETH Zurich
10. Jennifer von Schwerin, University of New Mexico

Unable to attend (but available by telephone if necessary):

11. Maurizio Forte, U California Merced
12. Nikolai Grube, University of Bonn
13. Eva Martinez, Honduran Institute of Anthropology and History (IHAH)
14. Heather Richards-Rissetto, PhD candidate, University of New Mexico

AGENDA

9:00-9:15 **Welcome and Introductions – Armin**

9:15-9:30 **Overview of Copan Start-Up Project and Zurich Workshop Goals – Jennifer**

9:30-10:15 **Review of April Copan Workshop – Jennifer**

- a. scope and content of the available Copan digital collections
- b. archaeological/art historical significance
- c. user needs – case uses of the material
- d. planned future work

10:15-11:45 **Review of Data Collection for 3D Copan Pilot Project – Armin**

- a. Summary of work completed to date
- b. Lessons learned - problems and challenges
- c. Current technological expertise, capabilities, and possibilities
- d. Planned short term future work – who does what?
- e. Deliverables for NEH White Paper and NEH/DFG grant proposal

11:45-12:15 **Previous Photogrammetric Research at Copan – Hasso Hohmann**

12:15 – 13:15 Lunch

13:15- 15:00 **Preparation of NEH White Paper/Future Project Funding**
Project Assessments, Work-packages, Timeframes, and Deliverables

A. 3D GIS-Database and Website Design/ Web Environment Requirements (Martin with Jennifer, Heather, Maurizio and Fabio)
GOAL: to develop a prototype platform that curates (in a searchable and virtual environment) selected digital collections on ancient architecture of Copan (and eventually other Maya cities)

B. 3D Model Planning (Armin with Jennifer, Henri, Fabio, and Maurizio)

GOAL: to create the most highly-accurate hybrid 3D model of an ancient Maya temple and its architectural sculpture to date, to be used on the website.

C. Requirements and Possibilities for website hosting, security, long-term maintenance (Jennifer)

(IHAH, ETHZ?, KAAK?, U Bonn?)

D. Assessment plan for the project. Prototype evaluation (Jennifer)

(Jennifer Habilitation project)

15:00-15:30 Coffee Break

15:30-16:15 Possible Future Project Funding

16:15 – 17:00 Other Emerging Projects

19:00 Dinner invitation by P&F (IGP)